

THE EFFECT OF VOCAL DISTRACTION UPON MENTAL WORK

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The Effect of Vocal Distraction Upon Mental Work

The writer is gratefully indebted to Professor Sylvestro Baglioni, Professor of Human Physiology at the University of Rome, for suggesting the problem treated in this dissertation and for directing the first series of experiments. To Professor R. S. Woodworth, the writer wishes to express his deep appreciation for his kindness and assistance in directing further experiments in the Laboratory of Experimental Psychology at Columbia University, which served as control for the experiments begun at Rome.

OUTLINE OF THE INVESTIGATION

The experiments to be reported in this paper can be classified under the head of distraction, though, like other distraction experiments that have been published, the results are rather to be classified under the head of facilitation. As in several previous investigations, a monotonously repeated speech movement has been introduced as a distracting factor in intellectual work. The intellectual work employed in the present study has consisted in the memorizing of unconnected material and in the addition of numbers. The distracting factor has consisted in the steady intoning by the subject of a note of constant pitch and of constant vowel sound. The vowel sound has been E (as in bed), and the pitch of the tone sung has been selected to suit each person who served as subject. Each subject first practiced sustaining this tone steadily while paying out a full breath of air, and then was required to memorize or to add while sustaining the tone, and also, for comparison, without the vocalized tone. This particular vocal performance was chosen because it fully occupies the larynx and because the adequacy of the subject's performance can be checked by observing the steadiness of his tone.

Originally suggested by Professor Baglioni, the experiment was first carried out in his laboratory of Human Physiology at the University of Rome, 1925. The present writer served

as both experimenter and subject in a long series of experiments, the results of which showed a definite facilitating effect of the "distracting" vocalization.

As a check on these results, the experiment was repeated in the Psychological Laboratory of Columbia University in 1927. Twenty-four subjects served each for a brief series; and the results showed that the intellectual work went on without any great disturbance from the vocalization. Some subjects appeared to be favorably affected and others rather adversely, but the experiment was not prolonged enough to make sure of genuine individual differences, and the group averages, while showing some advantage of the performance with vocalization, did not show a statistically reliable difference.

Accordingly the experiment was taken up again in the Columbia Laboratory in 1930, with sixteen subjects, each of whom served for a long series of trials, and all of whom showed the facilitation effect.

HISTORICAL

We limit our history strictly to literature bearing directly upon our problem.

1880—Stricker, S. S. After a long period, Stricker was able to read a newspaper while repeating aloud a ballad of Schiller.

1886—Paulham, M. During a prolonged vocalization of the vowel "A," Paulham was able to get images of all other vowels.

1894—Abell, A. M. Finding a marked correlation between slow reading and actual pronunciation of the words read, Abell believed that the process of articulation was a hindrance to reading, to its comprehension and assimilation.

1895—Baldwin, J. M. Baldwin believed it possible to think of different notes while holding the vocal cords in a rigidly fixed position. He asserted that it was possible to think of a particular note while articulating in a different pitch a vocal sound such as the vowel "A."

1895—Smith, T. L. Experimenting upon five subjects, this investigator found that distraction caused by counting aloud one, two, three; one, two, three, etc., produced 12.6% to 17.7% more errors in learning lists of ten nonsense syllables than when similar lists were learned without this distraction.

1895—Smith, W. G. A simple sum in addition, viz., that involved in repeating the series 2, 4, 6, 8 . . . or the series 3, 6, 9 . . . , caused greater distraction in learning twelve letters arranged in three lines than the simple repetition of the syllable *la*; tapping the table with the forefinger also caused distraction, but the effect was neither universal nor distinct. Twelve subjects were experimented upon.

1897—Quantz, I. O. In the case of motor readers, Quantz believed that placing the tip of the tongue under the upper lip hinders the free movements of the lips while reading. This hindrance should interfere with attention and thereby reduce the reading rate.

1899—Secor, W. B. From a study made at Cornell University, Secor found that his subjects could read a paragraph while whistling or while articulating a letter.

1900—Huey, E. B. In a group of twenty subjects, Huey found that articulating slowed the speed of reading. The subjects were requested to read pages of printed matter selected from a novel. Each page of printed matter contained four hundred and five words.

1906—Dearborn, W. F. Reading a passage aloud hinders the speed of reading because greater attention must be given to the parts of each particular word in pronouncing it.

1913—Pintner, R. Pintner submitted two subjects to reading passages of prose while repeating aloud the numerals 13, 14, 15, 16; 13, 14, 15, 16; etc. Pintner found that the subjects could read while repeating the numerals. He also found that the reading could be accomplished as quickly as when reading without articulation of the numerals. With practice, the articulation increased the ordinary rate of reading. Each subject was submitted to one hundred and three passages containing sixty to seventy-nine words, the average being seventy words for each passage. Sixty-three passages were read while articulating the numerals; forty passages were read without the articulation.

1916—Reed, H. B. Eight subjects were requested to read and write newspaper clippings while repeating aloud and rapidly the sentence "Jack and Jill ran down the hill." For comparison, each subject was submitted to a series of similar tests without the distraction. From the results obtained, Reed concluded that the distraction did not hinder comprehension, neither did it affect the rates of reading and writing. (It is implied that the reading and writing were in no way disturbed.) Four subjects were next submitted to series of problems in addition. The subjects were presented with six sheets containing sixteen single columns of twenty-eight digits each. Each subject was requested to add the columns on the second, third, fourth and fifth sheets with the distraction of "Jack and Jill ran down the hill"; the columns on the first and sixth sheets were added without the distraction. For two subjects the average number of columns added wrongly was greater with the distraction than without; for the other subjects the number of columns added wrongly was not affected by the distraction. For two subjects, the average sum of errors per sheet was increased by the distraction; in the case of the other two,

the distraction decreased the average number of errors per sheet. Considering the group of four subjects as a whole, Reed concluded that the distraction had no marked effect upon the quantity of errors. He was also of the opinion that the distraction did not markedly affect the adding time. Reed found that the distraction did not increase the adding time in all subjects.

1929—Bills, A. G. Studying the influence of muscular tension on the efficiency of mental work, Bills found that a moderate and steady squeeze on each of two dynamometers held in the hands increases the efficiency for learning words and nonsense syllables; the tension improves also the speed and accuracy of performance in adding columns of digits. These experiments apparently show that muscular tension increases the efficiency of mental work such as is involved in adding or memorizing.

TASKS PERFORMED BY THE SUBJECTS

The order of presentation of the tasks or problems depends (1) upon the subjects used, i.e., the writer versus others, and (2) upon the kind of task, i.e., memory versus addition.

I. PROBLEMS WHICH THE WRITER SUBMITTED TO HIMSELF:

A. *Memory Problems*

As memory problems, the writer submitted to himself nine lists of five nonsense syllables, nine lists of five combinations of mute consonants and semi-consonants, twenty-seven lists of five four place numbers, twenty-seven lists of ten short words, twenty-seven lists of twelve nonsense syllables and twenty-seven lists of twelve four place numbers. Each group of lists was subdivided into groups of threes. In each sub-group, the list marked 1 was learned while vocalizing the vowel "E," the list marked 2 was learned silently, the list marked 3 was learned aloud.

The groups of lists and their sub-groups are given below; the lists are presented in the rotating order in which they were given:

GROUP I.

LISTS OF FIVE NONSENSE SYLLABLES.

1. lonv, pomp, zeln, hamt, gimp
2. swez, glob, swem, nunv, lenb
3. sibs, gump, sbim, dolt, jnaq.
2. basf, sden, slir, munf, bmiz
3. bafd, spdf, nemz, thiq, gral
1. javb, dofs, silm, graz, zran.
3. stim, swep, rosb, woft, dunf
1. gowz, pirm, sviz, drab, tulf
2. smop, gorn, funt, swet, flob.

GROUP II.

LIST OF FIVE COMBINATIONS OF MUTE CONSONANTS AND SEMI-CONSONANTS.

1. htpj, qwfv, pdfb, hjst, wtsv
2. hgwd, fjp v, tfjs, sghd, fvpt
3. vwbh, jptf, wjsb, gsb f, ftpg.
2. hjfp, tjwg, fdhj, jpvt, stfb
3. gpb f, htsj, wjfh, sjwd, pdwg
1. hgwd, tfjs, dsgh, fvpt, vbtg.
3. hdsj, tfgw, pbwt, hjsd, svfg
1. fghg, dwfs, sbpd, fjhv, thds
2. ptwb, fjp v, gwbp, vsdh, jhfv.

GROUP III.

LISTS OF FIVE FOUR PLACE NUMBERS.

1. 8179, 3642, 7358, 4619, 2746
2. 8723, 6195, 7481, 9526, 5792
3. 9741, 8625, 1759, 6381, 7516.

2. 8579, 6421, 7295, 8364, 7258
3. 7316, 4952, 5197, 9256, 1738
1. 6153, 8297, 3815, 9628, 7469.

3. 4968, 9283, 5917, 1648, 6537
1. 1986, 3725, 5872, 3964, 8591
2. 1725, 8493, 2981, 7364, 5728.

1. 8163, 9524, 5813, 7926, 2753
2. 4869, 1527, 7493, 4738, 3124
3. 5386, 9728, 6153, 7968, 3124.

2. 9837, 3481, 6137, 8469, 5693
3. 1369, 5791, 4683, 9748, 6135
1. 3782, 5367, 7935, 6486, 9642.

3. 2568, 5429, 8769, 3652, 9428
1. 9473, 3856, 6593, 8271, 5784
2. 9652, 6284, 8361, 4972, 1728.

1. 4651, 9824, 3856, 9472, 6825
2. 8496, 3597, 2518, 7496, 8539
3. 1786, 6984, 4295, 3964, 8457.

2. 5186, 4923, 7542, 4869, 3485
3. 1853, 5796, 9347, 2674, 3841
1. 5263, 8924, 3786, 4312, 9247.

3. 2834, 5382, 4326, 1641, 6523
1. 3142, 5645, 4692, 6259, 2953
2. 3926, 9735, 7941, 5693, 4857.

GROUP IV.

LISTS OF TEN SHORT WORDS.

1. bell, scold, grass, pure, butter, pull, edge, frail, cap, try
2. king, learn, tin, thick, book, rap, judge, bald, church, transfer
3. class, fight, shoe, tough, hood, sooth, wick, dull, rice, tow.

2. tobacco, run, table, proud, hand, bake, yard, shabby, trip, pulsate
3. card, sweep, sting, foreign, window, cry, accent, angry, hand, ignore
1. apron, sit, brick, dandy, mat, provide, star, bare, baby, solve.

3. ruler, tease, lamp, easy, whip, insert, male, pious, fire, resent
1. grass, forbid, flow, sky, deer, strike, car, valid, heart, teach
2. screw, dumb, basket, idle, kiss, purge, jump, cheap, brush, reap.

1. apple, gallop, clock, sharp, knife, bite, book, hot, hat, boil
2. prevail, sleep, hand, dusty, dog, float, oyster, raw, church, growl
3. draw, sail, bird, deep, banner, roar, shoe, ripe, train, scratch.

2. finger, string, house, funny, coat, shoot, cart, tall, face, malt
3. baby, swim, fire, stormy, dog, explore, laborer, new, pencil, ache
1. army, blow, heart, hilly, pin, new, gun, strong, eyes, cat.

3. bird, cut, wind, muddy, lungs, fly, bell, pretty, music, burn
1. parrot, allow, clock, noisy, axe, assist, boom, white, mosquito, cease
2. oak, conceal, measles, steep, shark, certain, quinine, round, beef, demand.
1. canoe, devour, penny, smoke, diction, dilate, cabbage, curly, dog, gather
2. river, hire, sparrow, north, index, implore, rose, sour, color, predict
3. holiday, obtain, fish, out, tool, prolong, metal, weak, flower, retire.
2. coin, shut, city, good, insect, sooth, food, slow, fruit, surpass
3. disease, vanish, grain, sick, tree, read, month, large, ocean, tear
1. vanish, spin, bird, bad, boat, paint, paper, tall, bat, mail.
3. toe, throw, fruit, large, water, wail, ship, rich, pen, write
1. love, lock, summer, new, knife, wash, glove, dark, army, bake
2. head, came, bread, sick, news, open, snake, dense, horse, crawl.

GROUP V.

LISTS OF TWELVE NONSENSE SYLLABLES.

1. yauf, lilb, plok, huke, jids, molv, nalx, kefe, quad, guth, smud, dorz
2. nuft, chad, plen, drup, geth, leze, bilp, firg, kelk, horp, jare, noox
3. fink, dute, carb, jurg, moit, glél, quen, lape, plof, hask, norb, keme.
2. kirz, chaq, shib, stoz, rupt, lomf, noob, trid, jarn, zulx, himv, drus
3. yown, qued, ning, zaug, wowb, hank, thul, vels, dalt, sowg, veet, purs
1. mowt, yuve, fime, sark, thig, weeb, quix, nads, lorm, quag, chet, roop.
3. parl, toib, swef, roch, kive, yuns, filk, grud, zarz, neek, halg, daux
1. skot, reeb, clit, mods, dren, quor, walp, yang, laut, kenk, blad, pite
2. lers, fimp, noor, zoch, quaf, jirb, homv, cren, skux, kipe, poiz, raud.
1. wimv, rept, lont, vars, laum, trep, yaur, larb, kerv, losh, zers, plam
2. kerg, jind, lemv, maux, hoft, sowf, flex, volm, voom, dirs, glob, fabe
3. brap, mult, fir, komf, nowd, laux, yulm, dowz, sigs, queb, flod, clis.
2. rerb, drid, lerx, risk, noin, yurd, frag, nind, sowv, wuks, horx, von
3. helf, wuse, sulv, yute, kert, shil, deeb, thit, quan, naux, frul, perz
1. grem, munt, larf, doot, kimp, jite, blog, hoir, fint, gref, nafe, plep.
3. pran, kesh, morf, wike, lert, yoze, blid, feex, jast, voob, hink, nalp
1. yune, dars, theg, rilp, ceeb, voor, jath, quol, sibe, hoiv, naud, fruz
2. sarp, lilb, quex, zoct, reez, yuts, rerl, vaug, frau, moim, jike, gowg.
1. snod, bulb, narf, jilm, zalf, kire, quot, quoz, hake, yeen, swos, pime
2. yufs, zith, sern, chaz, timf, wenx, pupt, namp, qask, snud, jirp, kife
3. hade, nink, coiz, firf, jarp, bron, lact, kish, meel, dule, hild, grob.
2. wofs, hing, flet, varx, nasp, vood, thiv, dums, hoke, quaz, yook, delv
3. walm, zord, voox, quiv, peef, nide, lelb, jups, skag, caup, birk, vooz
1. sube, moir, fi, hend, kirg, zopt, duts, gliv, tow, reen, pauk, jarm.
3. jirg, glep, towf, swub, kize, voot, raul, deek, poix, zarl, sish, bame
1. nowf, luds, fleb, quog, clar, jile, swax, gun, tomp, herk, sizh, poid
2. nurd, hilf, zoig, chen, mauk, gimv, jert, glex, dooz, quab, filg, bipe.

GROUP VI.

LISTS OF TWELVE FOUR PLACE NUMBERS.

1. 5341, 3495, 2471, 5739, 7318, 9561, 5136, 7689, 6829, 1452, 6728, 3195
2. 4375, 7654, 4865, 1589, 4271, 5874, 8432, 5298, 6391, 1962, 1389, 1826
3. 3279, 6327, 4672, 9813, 4921, 3465, 8539, 7395, 3716, 2947, 3892, 4273.

2. 9836, 4216, 8379, 6945, 1725, 3914, 7468, 2158, 9237, 2964, 4263, 5787
3. 2159, 7549, 3629, 7835, 6275, 1978, 6431, 7314, 6965, 4173, 9437, 8658
1. 6541, 7394, 8659, 1462, 7634, 3271, 9452, 6936, 4253, 1729, 3248, 6374.

3. 9458, 6719, 2196, 8374, 3916, 7514, 8129, 5963, 7295, 4312, 7851, 5197
1. 1865, 4819, 7954, 3876, 5983, 2536, 4312, 2893, 8147, 1539, 6241, 5368
2. 8691, 4795, 4538, 6721, 1462, 3956, 6512, 7456, 2978, 4196, 1872, 9157.

1. 6945, 7549, 5897, 8145, 4796, 6357, 3158, 7483, 3548, 2486, 6358, 3294
2. 8723, 9238, 8673, 9634, 4359, 6723, 3128, 9641, 6945, 7193, 5942, 7349
3. 1589, 7865, 1954, 5498, 8172, 4328, 3567, 8736, 7293, 3821, 5967, 8546.

2. 8673, 9634, 6723, 3459, 3128, 9346, 5914, 7193, 9542, 3497, 7149, 6493
3. 4627, 9813, 4912, 3465, 8539, 7395, 3716, 2947, 3892, 4239, 7594, 1825
1. 7654, 4865, 1568, 1826, 4271, 5874, 8432, 5298, 6391, 1962, 3821, 1389.

3. 3258, 1985, 2596, 5614, 2893, 9268, 2153, 4369, 2864, 8257, 3679, 8526
1. 4612, 8715, 5246, 7145, 8517, 5913, 7624, 4357, 6725, 7846, 9164, 1238
2. 1649, 5389, 1794, 9852, 8751, 2943, 9756, 6857, 3786, 3548, 6358, 3294.

1. 8259, 6728, 8715, 7624, 4357, 6725, 7846, 9164, 1238, 5931, 4612, 5246
2. 9836, 4263, 6541, 8371, 4586, 2751, 5139, 1975, 9186, 3978, 7145, 8517
3. 8647, 2358, 1985, 2596, 5614, 2819, 2968, 2153, 4369, 2864, 8257, 2687.

2. 2471, 5793, 7318, 9561, 5136, 7689, 6892, 1453, 6728, 3195, 2374, 4951
3. 7191, 1458, 5874, 6258, 8921, 7643, 1248, 7829, 2536, 3154, 1695, 5284
1. 5168, 4923, 9172, 4869, 3412, 9256, 3715, 5689, 2437, 8694, 3125, 7351.

3. 4253, 1789, 6389, 9154, 7293, 6748, 1256, 4931, 2754, 7495, 4938, 5316
1. 5213, 4968, 7342, 9861, 5713, 6529, 8143, 9468, 5729, 7143, 4861, 4521
2. 3516, 7942, 9624, 2431, 8615, 1587, 3549, 4167, 3795, 6813, 5321, 7532.

B. Addition Problems

As addition problems, the writer submitted to himself ninety lists of forty-five one place numbers and two groups consisting respectively of ninety lists of fifteen two place numbers. The ninety lists of forty-five one place numbers and the two groups of ninety lists of fifteen two place numbers were respectively subdivided into groups of threes. In each sub-group of the ninety lists of one place numbers, and in each sub-group of the first group of ninety lists of two place numbers, the list marked 1 was added while vocalizing the vowel "E," in each sub-group of the second group of ninety lists of two place numbers, the list marked 1 was added while making expulsions of "Pe." In all sub-groups, the lists marked 2 were added silently; the lists marked 3 were added aloud.

As samples, the first twelve sub-groups of lists from each major group are given below. The lists are presented in the rotating order in which they were given.

GROUP I.
LISTS OF FORTY-FIVE ONE PLACE NUMBERS.

1	2	3	2	3	1	3	1	2	1	2	3	2	3	1	3	1	2
6	5	9	9	1	6	1	2	5	9	2	4	6	9	3	4	9	9
1	2	5	4	5	8	6	4	2	2	3	8	8	3	6	1	2	6
8	9	7	8	7	1	9	5	6	4	8	3	3	8	4	3	8	2
5	1	6	1	3	4	7	8	4	7	4	6	7	4	1	5	6	4
4	7	4	2	6	9	5	7	1	5	9	9	1	1	7	2	5	1
7	6	8	7	9	2	2	9	8	1	6	7	9	5	9	6	1	8
2	4	2	5	2	3	4	6	9	6	5	1	5	7	5	9	7	3
9	3	1	3	8	7	8	3	3	8	1	5	2	2	8	7	5	7
3	8	3	6	4	5	3	1	7	3	7	2	4	6	2	8	4	5
4	4	9	1	2	2	5	7	9	1	4	6	8	8	5	1	7	3
4	1	2	8	1	6	1	5	6	7	8	5	3	7	9	4	3	9
2	2	6	2	8	4	4	1	2	3	6	3	5	2	2	7	8	7
3	3	4	9	4	8	8	6	1	9	9	7	4	6	6	2	5	4
9	9	8	6	7	9	3	8	8	2	2	2	6	4	1	5	1	6
3	5	7	3	9	5	6	4	4	6	7	4	9	9	4	8	9	8
1	7	5	5	6	7	9	2	3	4	1	9	7	1	7	3	2	5
8	8	3	7	3	3	2	9	7	8	3	8	1	5	3	9	4	1
2	6	1	4	5	1	7	3	5	5	5	1	2	3	8	6	6	2
5	9	3	6	8	9	8	8	8	8	4	8	6	7	2	1	8	8
8	4	9	4	2	6	7	1	4	9	9	7	8	4	9	8	5	1
3	2	1	7	9	7	9	7	9	5	8	1	2	8	3	4	3	9
9	7	8	5	1	4	3	2	7	2	2	6	9	3	7	9	1	6
2	6	4	2	4	3	1	3	2	4	6	3	1	9	4	3	4	2
6	3	2	1	7	5	6	4	3	1	7	5	7	5	6	7	2	7
4	8	6	3	5	1	2	9	6	3	3	4	3	3	8	5	7	5
1	1	5	8	3	8	4	6	1	7	5	9	4	1	5	2	9	3
7	5	7	9	6	2	5	5	5	6	1	2	5	6	1	6	6	4
8	7	4	6	2	6	8	2	3	7	2	9	9	9	3	1	8	9
1	5	6	5	4	8	3	5	9	5	4	2	6	2	6	5	2	6
9	8	8	7	8	3	1	1	4	9	3	5	8	8	2	7	5	1
6	1	5	4	6	2	4	3	5	3	9	6	4	6	7	8	3	4
4	4	9	1	3	1	7	8	2	2	7	8	7	3	5	6	9	8
7	2	2	3	9	4	2	4	8	6	1	7	3	1	8	4	7	3
3	6	1	8	7	9	9	7	6	4	5	3	5	4	9	9	1	7
5	3	7	2	1	5	5	9	3	1	8	1	1	7	9	3	6	5
2	9	3	9	5	7	6	6	1	8	6	4	2	5	1	2	4	2
6	4	8	1	7	9	3	1	6	6	8	6	1	8	3	8	2	9
1	9	2	5	8	7	6	9	8	1	1	7	5	3	5	1	8	5
3	6	1	9	4	3	2	2	7	5	2	5	8	7	7	5	3	3
5	8	3	6	1	6	7	4	5	9	7	9	6	9	2	2	7	1
8	2	5	3	6	1	5	5	4	8	9	2	2	2	6	4	9	4
4	7	7	7	9	8	1	9	2	4	4	8	4	5	9	7	4	2
2	5	4	2	5	4	8	6	1	3	5	3	9	1	1	9	1	8
9	3	9	4	2	2	4	3	3	7	3	1	3	4	4	6	5	6
7	1	6	8	7	5	9	7	9	2	6	4	7	6	8	3	6	7
5	6	4	9	2	5	4	9	8	2	7	1	6	7	3	4	8	7
2	2	7	2	7	7	6	1	3	3	1	6	9	5	1	2	4	9
9	7	8	7	1	9	5	4	5	4	4	9	4	1	5	1	1	6
4	4	5	3	6	1	9	3	4	7	9	3	2	8	8	3	3	1
1	8	1	6	3	6	3	6	6	6	6	5	5	3	4	8	9	4

GROUP I.—(Continued)

LISTS OF FORTY-FIVE ONE PLACE NUMBERS.

1	2	3	2	3	1	3	1	2	1	2	3	2	3	1	3	1	2
6	3	9	4	4	8	8	2	5	8	2	8	1	6	7	6	2	2
3	1	3	1	8	3	2	7	8	1	8	4	8	9	9	9	7	5
9	5	2	5	7	2	1	8	1	9	3	7	3	4	2	7	5	3
8	9	6	8	5	4	7	2	7	5	5	2	7	2	6	5	6	8
6	2	8	1	9	1	1	4	2	3	8	9	2	6	8	3	9	6
9	8	3	5	5	3	6	7	7	8	4	4	6	8	2	9	1	9
4	1	1	2	4	6	9	3	9	7	5	2	4	4	9	6	7	3
1	9	6	8	8	2	7	2	3	6	3	7	7	2	1	1	4	8
3	5	2	3	1	9	2	9	5	9	1	5	1	5	7	5	8	4
5	7	7	7	6	5	8	8	1	2	7	1	9	3	5	8	6	2
2	4	4	9	3	8	5	7	6	5	9	3	5	9	6	4	3	5
7	6	5	4	2	7	3	1	4	1	6	8	3	1	4	2	5	7
8	3	9	6	7	4	4	5	8	4	2	6	8	7	3	7	2	1
4	5	6	1	5	9	7	7	1	9	8	8	6	3	5	5	9	2
2	6	8	2	7	6	1	8	5	1	5	1	8	9	1	3	3	8
9	1	5	6	6	8	9	3	9	8	1	6	7	4	9	7	8	4
1	7	1	7	9	3	6	5	3	6	7	2	1	2	6	8	5	9
8	4	3	4	3	5	8	9	6	2	9	9	5	7	3	1	2	3
6	8	9	3	8	7	5	2	2	4	2	7	9	8	8	9	1	7
3	2	4	9	1	2	2	6	4	9	6	3	4	1	4	6	6	5
7	9	7	8	4	4	3	1	7	3	3	5	2	6	7	4	4	1
5	3	2	4	2	1	4	4	8	5	4	4	3	5	2	2	7	6
2	7	9	9	6	3	8	1	3	6	8	6	9	4	9	7	5	2
7	9	4	3	3	9	2	8	1	3	5	3	2	2	1	5	2	7
5	1	6	7	5	6	4	2	4	1	9	1	7	5	8	6	9	1
8	6	2	1	2	8	7	7	6	5	4	2	3	8	7	1	1	4
3	2	1	8	4	4	1	3	8	9	2	4	6	6	4	4	4	6
6	5	5	5	8	7	9	6	5	7	6	7	8	1	5	9	6	8
9	3	8	6	3	2	3	5	7	8	3	5	4	9	3	2	8	5
1	8	3	2	7	5	5	9	9	2	7	9	1	2	6	3	1	9
4	4	7	4	9	1	6	4	2	4	1	8	5	7	2	8	7	3
3	6	4	2	4	3	3	2	6	7	9	3	2	5	4	2	3	6
5	8	9	4	8	5	6	6	2	4	7	7	6	9	6	7	9	2
7	5	3	3	1	8	9	3	8	3	1	1	3	4	3	4	4	8
2	9	8	5	2	7	5	7	3	6	6	5	5	8	1	9	2	3
6	3	1	8	7	6	2	9	7	1	8	8	9	3	9	5	7	5
9	1	7	6	3	1	8	3	4	9	2	4	4	7	5	3	5	7
4	7	5	9	9	2	4	8	9	3	5	6	7	2	7	6	1	9
8	2	2	7	6	7	7	4	5	5	3	9	8	6	2	8	8	1
1	4	6	1	5	4	1	5	2	2	4	2	1	1	8	1	6	4

GROUP II.

FIRST GROUP OF LISTS OF TWO PLACE NUMBERS.

<i>1</i>	<i>2</i>	<i>3</i>	<i>2</i>	<i>3</i>	<i>1</i>	<i>3</i>	<i>1</i>	<i>2</i>	<i>1</i>	<i>2</i>	<i>3</i>	<i>2</i>	<i>3</i>	<i>1</i>	<i>3</i>	<i>1</i>	<i>2</i>
51	49	76	39	52	23	71	13	42	21	14	49	91	29	43	12	64	65
76	64	51	85	13	39	55	71	13	73	55	21	17	32	91	48	23	64
64	76	32	23	85	13	13	42	31	49	73	55	29	17	32	65	48	23
49	32	64	52	39	85	31	55	71	14	49	73	43	91	29	23	12	48
32	51	49	13	23	52	42	31	55	55	21	14	32	43	17	64	65	12
83	79	17	51	83	64	17	79	22	12	53	74	59	34	63	47	55	73
17	95	79	43	57	55	93	22	85	89	68	12	63	98	42	68	73	55
95	28	83	64	55	43	79	85	93	53	74	89	34	42	98	53	47	68
28	17	95	83	43	57	22	17	79	68	12	53	98	59	34	73	68	53
79	83	28	55	64	83	85	93	17	74	89	68	42	63	59	55	53	47
58	92	43	28	54	37	69	42	27	83	76	46	13	37	96	58	29	95
43	61	58	75	28	85	27	69	54	33	31	93	62	96	13	43	54	29
61	58	25	54	37	28	54	27	87	76	93	31	37	62	71	95	43	54
25	43	92	37	85	75	87	54	42	31	46	33	96	71	62	29	58	43
92	25	61	85	75	54	42	87	69	46	33	76	71	13	37	54	95	58
<i>1</i>	<i>2</i>	<i>3</i>	<i>2</i>	<i>3</i>	<i>1</i>	<i>3</i>	<i>1</i>	<i>2</i>	<i>1</i>	<i>2</i>	<i>3</i>	<i>2</i>	<i>3</i>	<i>1</i>	<i>3</i>	<i>1</i>	<i>2</i>
16	68	49	51	23	62	46	18	22	66	71	22	19	58	14	27	42	67
52	16	27	23	59	17	18	77	46	35	18	66	46	19	51	62	14	42
49	52	16	62	17	59	77	46	54	71	35	18	58	46	38	19	51	14
68	27	52	17	51	23	22	54	77	22	66	71	27	62	43	46	67	38
27	49	68	59	62	51	54	22	18	18	22	35	62	27	67	58	38	51
72	82	54	56	31	92	61	82	26	27	94	84	56	35	59	86	79	37
51	54	37	44	56	73	49	61	82	84	27	59	43	78	48	56	59	79
37	72	82	92	44	56	82	49	78	59	32	94	78	86	68	43	37	48
82	51	72	73	92	31	78	26	61	32	59	27	86	56	79	35	68	59
54	37	51	31	73	44	26	78	49	94	84	32	35	43	37	78	48	68
62	33	47	36	19	67	31	72	62	68	43	14	94	36	74	71	41	56
47	79	58	19	77	82	39	77	72	98	14	43	25	71	39	53	69	74
58	47	62	67	82	19	62	31	77	43	68	56	36	53	41	25	56	39

GROUP III.

SECOND GROUP OF LISTS OF TWO PLACE NUMBERS.

<i>1</i>	<i>2</i>	<i>3</i>	<i>2</i>	<i>3</i>	<i>1</i>	<i>3</i>	<i>1</i>	<i>2</i>	<i>1</i>	<i>2</i>	<i>3</i>	<i>2</i>	<i>3</i>	<i>1</i>	<i>3</i>	<i>1</i>	<i>2</i>
61	24	83	28	16	53	41	94	71	36	75	43	43	69	36	21	66	13
24	58	36	84	91	28	37	29	41	29	89	36	86	28	56	13	77	66
58	61	28	91	53	16	29	71	37	89	43	29	24	36	83	66	95	21
43	86	56	16	84	91	94	41	29	43	36	75	61	83	69	95	13	77
86	43	69	53	28	84	71	37	94	75	29	89	24	56	28	77	21	95
45	19	31	68	34	92	91	54	28	47	92	74	69	84	24	37	49	61
69	71	24	24	68	86	54	43	86	51	38	92	19	31	68	49	61	37
98	45	68	35	92	68	86	28	91	92	51	47	71	95	84	96	37	59
71	98	84	92	86	23	43	91	54	74	47	38	43	68	95	61	59	96
19	69	95	86	24	35	28	86	43	38	74	51	98	24	31	59	96	49
26	83	27	29	15	73	63	37	45	62	95	57	71	38	52	43	74	37
83	54	38	15	98	29	45	63	76	41	62	95	45	98	64	57	68	43
54	45	64	64	29	98	58	76	37	95	24	62	26	27	98	68	37	74
71	26	98	98	73	64	37	58	63	24	57	41	83	52	27	74	43	57
45	71	52	73	64	15	76	45	58	57	41	24	54	64	38	37	57	43
<i>1</i>	<i>2</i>	<i>3</i>	<i>2</i>	<i>3</i>	<i>1</i>	<i>3</i>	<i>1</i>	<i>2</i>	<i>1</i>	<i>2</i>	<i>3</i>	<i>2</i>	<i>3</i>	<i>1</i>	<i>3</i>	<i>1</i>	<i>2</i>
96	27	73	22	13	97	96	65	74	79	86	32	52	89	21	75	94	56
45	31	96	13	75	61	37	12	65	51	24	79	74	52	36	18	75	29
31	45	27	61	26	13	12	74	96	24	79	51	21	36	74	56	29	18
73	96	45	75	97	26	74	37	12	32	51	86	89	21	52	29	18	94
27	73	31	97	61	75	65	96	37	86	32	24	36	74	89	94	56	75
16	85	79	29	45	91	38	41	75	41	84	62	81	26	93	37	89	78
24	79	16	54	83	29	75	38	86	84	98	41	15	81	87	56	78	37
85	16	93	83	91	45	62	75	41	17	62	98	26	93	15	89	42	56
93	24	85	91	54	83	86	62	38	62	41	17	93	87	81	42	37	89
79	93	24	45	29	54	41	86	62	98	17	84	87	15	26	78	56	42
93	24	75	19	63	84	68	23	15	36	59	18	65	49	52	67	16	93
24	51	36	71	84	42	15	92	23	72	36	94	52	96	17	93	67	32
51	75	24	63	71	19	92	81	68	94	18	72	96	17	65	32	71	67
36	93	51	84	42	71	81	15	92	18	72	59	17	52	49	16	32	71
75	36	93	42	19	63	23	68	81	59	94	36	49	65	16	71	93	16

II. PROBLEMS WHICH THE WRITER SUBMITTED TO OTHER SUBJECTS.

The forty subjects, who besides the writer served as subjects of experiment, were divided into four groups. The first and second groups of subjects consisted of twelve subjects respectively; the third and fourth groups of subjects consisted of eight subjects respectively. To the subjects of the first group were given memory problems; to the subjects of the second, third and fourth groups were given problems in addition.

A. Memory Problems

Six lists of five four place numbers, six lists of twelve nonsense syllables and six lists of twelve four place numbers were given as memory problems to each subject of the first group. Each group of lists was subdivided into three groups consisting of two lists respectively. In each sub-group, the list marked 1 was learned while vocalizing the vowel "E," the list marked 2 was learned silently.

Each group of lists together with its sub-groups is given below. The lists are presented in the rotating order in which they were given.

GROUP I.

LISTS OF FIVE FOUR PLACE NUMBERS.

1. 9473, 3856, 6593, 8271, 5784
2. 2568, 5429, 8769, 3652, 9428
2. 4651, 9824, 3856, 9472, 6325
1. 1736, 6984, 4295, 3964, 8457
1. 5168, 4923, 7542, 4869, 3485
2. 6153, 8297, 3815, 9628, 7469

GROUP II.

LISTS OF TWELVE NONSENSE SYLLABLES.

1. yauf, lulb, plok, huke, jids, molv, nalx, kefe, quad, guth, amud, dorz
2. wimv, rept, lont, vars, laum, trep, yaur, larb, korv, losh, zers, plam
2. nuft, chad, plen, drup, geth, leze, bilp, firg, kelk, horp, jare, noox
1. kerg, jind, lemv, maux, hauf, sowf, fleck, wolm, voom, dirs, gleb, fabe
1. fink, dute, carb, jurg, moit, glél, quen, lape, plof, hask, norb, kome
2. brap, mult, firK, komf, nowd, laux, yulm, dowz, sigs, greb, flod, elis

GROUP III.

LISTS OF TWELVE FOUR PLACE NUMBERS.

1. 5341, 3495, 2471, 5793, 7318, 9561, 5136, 7689, 6829, 1452, 6728, 3189
2. 6945, 7549, 5897, 8145, 4796, 6357, 3158, 7483, 3548, 2486, 6358, 3294
2. 4375, 7654, 4865, 1586, 1826, 4271, 5874, 5298, 6391, 1962, 8432, 3189
1. 8723, 9238, 8673, 9634, 4359, 6723, 3128, 9641, 6954, 7193, 5942, 7349
1. 3279, 6327, 4672, 9813, 4921, 3465, 8539, 7395, 3716, 2947, 3892, 4273
2. 1589, 7865, 1954, 5498, 8172, 4328, 3567, 8736, 7293, 3821, 5967, 8546

B. Addition Problems

Ten lists of forty-five one place numbers were given as addition problems in eleven subjects of the second group; ten lists of fifteen two place numbers were given as addition problems to twelve subjects of this group. One hundred and eighty lists of addition problems divided into sets of sixty were given to each subject of the third and fourth groups. The three sets of problems were given at different sittings, at two-day intervals. To the subjects of the third group were given sets of problems with one place numbers; to the subjects of the fourth group were given sets of problems with two place numbers.

Each group or set of lists presented to a subject was subdivided into two groups. In each sub-group the lists marked 1 were added while vocalizing the vowel "E"; the lists marked 2 were added silently. As examples are given the groups of lists (sub-groups included) submitted to the second group of subjects. The lists are presented in the rotating order in which they are given.

GROUP I.

LISTS OF FORTY-FIVE ONE PLACE NUMBERS.

1. 627483159281957464561748293791625384685931724
2. 364179582592614738293746851362758491357269148
2. 962418375397468512819627534961483752953142867
1. 928651754738519246853142796825397164283794156
1. 413526978147258396184937526157864932815247963
2. 529416398694135278429186375275836914357269481
2. 683719524835469712682917345968473512158624937
1. 478519326816274596851394729462158374938175326
1. 938415726872649153748395316928631475837925146
2. 579168324136295874968357241396847251358761274

GROUP II.

LISTS OF FIFTEEN TWO PLACE NUMBERS.

- | | | | | | | | | | | | | | | | |
|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|
| 1. | 49 | 64 | 76 | 32 | 51 | 79 | 95 | 28 | 17 | 83 | 92 | 61 | 58 | 43 | 25 |
| 2. | 13 | 71 | 42 | 55 | 31 | 79 | 22 | 85 | 17 | 93 | 42 | 69 | 27 | 54 | 87 |
| | | | | | | | | | | | | | | | |
| 2. | 23 | 39 | 13 | 85 | 52 | 64 | 51 | 43 | 57 | 83 | 37 | 85 | 28 | 75 | 54 |
| 1. | 71 | 55 | 13 | 31 | 42 | 17 | 93 | 79 | 22 | 85 | 69 | 27 | 54 | 87 | 42 |
| | | | | | | | | | | | | | | | |
| 1. | 52 | 13 | 85 | 39 | 23 | 83 | 57 | 55 | 43 | 64 | 57 | 28 | 37 | 85 | 75 |
| 2. | 39 | 85 | 23 | 52 | 13 | 51 | 43 | 64 | 83 | 55 | 28 | 75 | 54 | 37 | 85 |
| | | | | | | | | | | | | | | | |
| 2. | 21 | 73 | 29 | 14 | 55 | 12 | 89 | 53 | 68 | 74 | 93 | 33 | 76 | 31 | 46 |
| 1. | 76 | 51 | 32 | 64 | 49 | 17 | 79 | 83 | 95 | 28 | 43 | 58 | 25 | 92 | 61 |
| | | | | | | | | | | | | | | | |
| 1. | 42 | 13 | 31 | 74 | 55 | 22 | 85 | 93 | 79 | 17 | 27 | 54 | 87 | 42 | 69 |
| 2. | 51 | 76 | 64 | 49 | 32 | 83 | 17 | 95 | 28 | 79 | 58 | 43 | 61 | 25 | 92 |

ORDER IN WHICH PROBLEMS WERE GIVEN TO THE WRITER AND
FIRST TWO GROUPS OF SUBJECTS

I. Problems Which the Writer Submitted to Himself

The memory problems were given first. The order in which these problems were successively given was as follows:

1. Lists of five nonsense syllables.
2. Lists of five combinations of mute consonants and semi-consonants.
3. Lists of five four place numbers.
4. Lists of ten short words.
5. Lists of twelve nonsense syllables.
6. Lists of twelve four place numbers.

The problems in addition were given after the memory problems. The order was as follows:

1. Lists of forty-five one place numbers.
2. First group of two place numbers.
3. Second group of two place numbers.

*II. Problems Which the Writer Submitted to First
and Second Groups of Subjects*

The following was the order in which the memory problems were given to the first group of twelve subjects:

1. Lists of five four place numbers.
2. Lists of twelve nonsense syllables.
3. Lists of twelve four place numbers.

The addition problems were given to the second group of twelve subjects as follows:

1. Lists of forty-five one place numbers.
2. Lists of fifteen two place numbers.

PURPOSE OF PROBLEMS

MEMORY PROBLEMS

The nine lists of five nonsense syllables (p. 6), the nine lists of five combinations of mute consonants and semi-consonants (p. 7), the twenty-seven lists of five four place numbers (p. 8), the twenty-seven lists of ten short words (p. 9), the twenty-seven lists of twelve nonsense syllables (p. 10) and the twenty-seven lists of twelve four place numbers (p. 11) were given to the writer in order to compare performance in memory when learning while vocalizing the vowel "E" with performance in memory when learning silently or aloud.

The six lists of five four place numbers (p. 17), the six lists of twelve nonsense syllables (p. 18) and the six lists of twelve four place members (p. 18) were given to the first group of twelve subjects in order to compare these subjects' performance in memory while vocalizing the vowel "E" with performance in memory when learning silently.

ADDITION PROBLEMS

The lists of forty-five one place numbers (samples, pp. 13-14) and the first group of lists of two place numbers (samples, p. 15) were given to the writer in order to compare performance in addition while vocalizing the vowel "E" with performance in addition when adding silently or aloud; the second group of lists of two place numbers (samples, p. 16) were given in order to compare performance in addition when making expulsions of "Pe" with performance in addition when adding silently or aloud.

Lists of forty-five one place numbers (samples, p. 19) and lists of fifteen two place numbers (samples, p. 19) were given to other subjects (subjects of the second, third and fourth groups) in order to compare performance in addition when vocalizing the vowel "E" with performance in addition when adding silently.

PREPARATION OF PROBLEMS

The memory lists submitted to the writer and first group of subjects as well as the addition lists submitted to the writer

and second group of subjects were prepared by Professor Boggioni's laboratory assistants. Precautions were taken not to acquaint the writer with the nature of the lists since he was to serve as subject. Each group of lists was placed in an envelope. On the envelope was written the purpose and nature of the lists. The addition lists given to the third and fourth groups of subjects were prepared by the writer.

All lists were typed, double-spaced, on strips of heavy type-writing paper. The strips of paper were sufficiently wide to leave a margin of one-half inch on either side of the lists; they were also sufficiently long to leave a margin of one inch at either end of the lists.

The following precautions were taken in preparing the different groups of lists:

A. Memory Problems

I. Lists of five combinations of mute consonants and semi-consonants:

1. To compose each combination with four letters (mute consonants and semi-consonants).

2. To avoid repeating the same mute consonant or semi-consonant in a given combination.

3. To avoid repeating the same combination in a given list.

4. To avoid repeating the same combination in two or more lists.

II. Lists of five four place numbers and lists of twelve four place numbers:

1. To avoid as much as possible repeating the same number in a given combination.

2. To avoid repeating the same combination in a given list.

3. To avoid repeating the same combination in two or more lists.

4. In each list to avoid as much as possible repeating the same number in the same position in two or more consecutive combinations.

III. Lists of ten short words:

1. To compose each list with five nouns, three verbs and two adjectives.

2. To arrange the words in the order of noun, verb, noun, adjective; noun, verb, noun, adjective; noun, verb.

3. To employ words not exceeding three syllables, the shortest words being most desired.
4. To avoid repeating the same word in a given list.
5. To avoid employing a word for more than one list.

The lists of words were prepared from two sources. Most of the words were taken from lists of nouns, adjectives and verbs used for experimental purposes in the elementary course of experimental psychology at Columbia University. Some of the words were taken from a dictionary.

IV. Lists of five nonsense syllables and list of twelve nonsense syllables:

1. To avoid repetition of a syllable in a given list.
2. To avoid repetition of a syllable in other lists.

The lists of syllables were prepared from lists of nonsense syllables used for experimental purposes in both the elementary and advance courses of experimental psychology at Columbia. Most of the lists of twelve nonsense syllables were identical with the lists employed in the above mentioned courses.

B. Addition Problems

I. Lists of forty-five one place numbers:

1. To make the lists of about equal difficulty.
2. In each list to repeat each number from one to nine inclusively five times.¹
3. To avoid two or more consecutive numbers being the same.
4. To avoid concentrating the smaller or larger numbers in any particular part of the list.

II. Lists of fifteen two place numbers:

1. To make the lists approximately equivalent with respect to size of two place numbers used.
2. The number of smaller numbers and the number of larger numbers being about the same in each list.
3. To avoid two or more consecutive numbers from being the same.
4. To avoid concentrating the smaller or larger numbers in any particular part of a list.

¹ A study of the lists reveals that this instruction was not always rigidly observed. In some lists, some of the numbers were repeated four times, whereas other numbers were repeated six times.

APPARATUS

A. Apparatus Used When the Writer Served as Subject of the Experiment. (Laboratory of Human Physiology, Rome)

1. A laboratory table (about 2 m. x 1 m.).
2. A Bernardo wet spirometer (similar in type to a standard wet spirometer).
3. A Baglioni reed pedal organ.
4. A metronome with bell attached.
5. A stop watch.

B. Apparatus in the Columbia Laboratory With First and Second Groups of Subjects:

1. A laboratory table (about 2 m. x 1 m.).
2. A standard wet spirometer.
3. An Ellis reed pedal organ.
4. A stop watch.

PURPOSE OF APPARATUS

Spirometers: The spirometers were used in order to inspire and expire one hundred and fifty to two hundred and fifty cubic inches of air while vocalizing the vowel "E." In the case of the writer, the Bernardo spirometer was also used for inspiring and expiring a certain quantity of air (250 cubic inches of air) while making expulsions of "Pe."

Organs: The organs were used in order to sound the tone most suitable for the subjects to sing while vocalizing the vowel "E." In the case of the writer, the Baglioni pedal organ was also used for sounding the tone most suitable for making the expulsions of "Pe."

Metronome and stop watches: The metronome and the two stop watches were used for controlling time.

ARRANGEMENT OF APPARATUS FOR EXPERIMENTATION

The arrangement of the apparatus is best presented in the following figures (diagrams). Diagram I gives the arrangement of the apparatus when the writer served as subject. (It must be understood that the writer experimented upon himself, i.e., he was both subject and experimenter at the same time.) Diagram II gives the arrangement of apparatus when others served as subjects.

DIAGRAM I.

ARRANGEMENT OF APPARATUS WHEN WRITER SERVED AS SUBJECT.

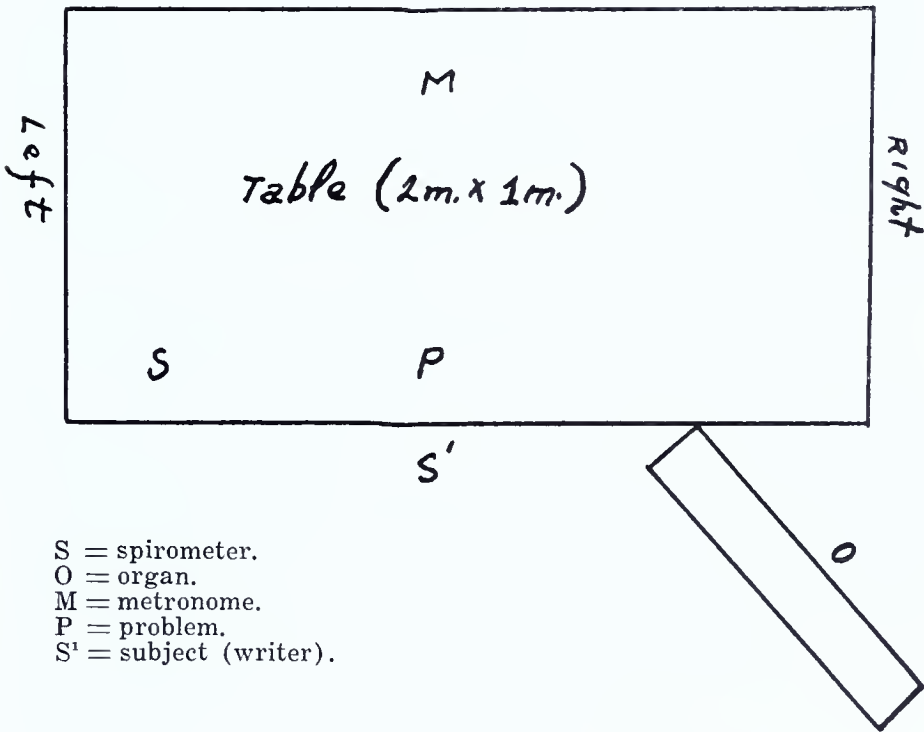
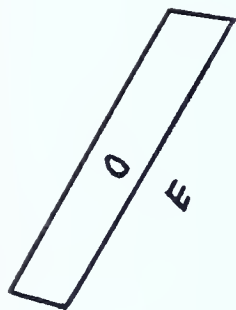
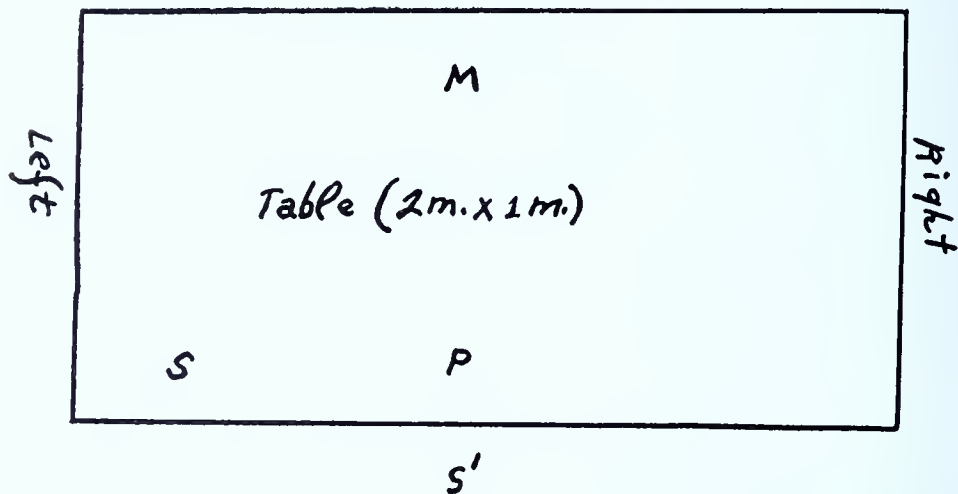


DIAGRAM II.
ARRANGEMENT OF APPARATUS WHEN OTHERS SERVED AS SUBJECTS.



S = spirometer.
O = organ.
P = problem.
S' = subject.
E = experimenter.

PROCEDURES OF EXPERIMENTATION

A. Procedures Involved When the Writer Served as Subject of Experiment

Preparatory to the presentation of the problem lists, the writer practiced nine hundred times expiring two hundred and fifty cubic inches of air while vocalizing the vowel "E" at the pitch of three hundred and nine double vibrations.² The practice series consisted in inspiring the above quantity of air from the Bernardo wet spirometer after having made three full inspirations, each inspiration being followed by a full expiration. The two hundred and fifty cubic inches of air were inspired immediately after the third expiration. Before inspiring the two hundred and fifty cubic inches of air and during the entire duration of its expiration, the tone of three hundred and nine double vibrations was given continuously by the Baglioni reed pedal organ.

I. Procedure in Memory Problems

As already stated above, in each group of memory lists submitted to the writer, the lists marked 1 were learned while vocalizing the vowel "E," the lists marked 2 were learned silently, the lists marked 3 were learned aloud. The numerals, 1, 2, 3 were written on the blank side of the lists, the writer took the lists from the envelope in which they were contained and placed them blank side up in a box just large enough to contain them. Care was taken to see that the lists appeared blank side up in the rotating order of 1, 2, 3; 2, 3, 1; 3, 1, 2; 1, 2, 3; 2, 3, 1; 3, 1, 2; etc.

Procedure for learning lists while vocalizing the vowel "E":

The lists were learned while vocalizing the vowel "E" at the pitch of three hundred and nine double vibrations. The duration of the vocalization was determined by the time required to expire two hundred and fifty cubic inches of air inspired from the Bernardo wet spirometer; the time was measured by a stop watch. During the entire duration of the vocalization of the vowel, the tone of three hundred and nine double vibrations was given continuously by the Baglioni reed

² The pitch of three hundred and nine double vibrations was found to be the pitch at which the writer could best vocalize the vowel "E."

pedal organ. The continuous sounding of the tone was made possible by placing a weight on the organ's key corresponding to the tone and by working one of the pedals with the left foot.

Below is reported in detail the procedure for learning the lists:

1. The spirometer was set at two hundred and fifty cubic inches.

2. The list to be learned was taken from the box in which it was contained and was placed blank side up on the table in the place indicated by the letter "P" in diagram I and II.

3. The tone of three hundred and nine double vibrations was sounded continuously from this moment until the list was finally learned.

4. Three full inspirations and three full expirations were made. Immediately after the third expiration the two hundred and fifty cubic inches of air were inspired from the spirometer.

5. As soon as the two hundred and fifty cubic inches of air were inspired, the writer began to vocalize the vowel "E," started the stop watch which was held in the left hand and turned the list right side up. He began to learn the list as soon as it was turned right side up.

6. Immediately after having expired the two hundred and fifty cubic inches of air, the stop watch was stopped and the list was turned blank side up. The time taken to expire the two hundred and fifty cubic inches of air was recorded. The list was pushed to the right side of the table and a blank sheet of paper was placed in its original place. The stop watch was reset at 0, the spirometer at two hundred and fifty cubic inches.

7. As soon as the spirometer was reset at two hundred and fifty cubic inches, three full inspirations and three full expirations were made again. At the termination of the third expiration, the two hundred and fifty cubic inches of air were inspired from the spirometer.

8. Immediately after having inspired the two hundred and fifty cubic inches of air, the writer began to vocalize the vowel "E," started the stop watch and began to write on the blank sheet of paper whatever he recalled of the list.

9. When the two hundred and fifty cubic inches of air had been expired, the stop watch was stopped. The sheet of paper on which the experimenter (writer) had been writing was turned blank side up and was pushed into the upper left corner of the table. The time registered by the stop watch was recorded. The memory list, now located at the right side of the

table, was replaced in its original place. In replacing the list, care was taken to keep the list blank side up. The stop watch was reset at 0, the spirometer at two hundred and fifty cubic inches.

10. The writer prepared to learn the list again as described in steps 4, 5 and 6, and reproduced it as described in steps 7, 8 and 9.

In the above manner, the list was learned and reproduced alternately until four correct reproductions were made in succession.

Procedure for learning lists silently :

Each exposure and each reproduction of the lists were limited respectively to thirty seconds. The time was controlled by a metronome and stop watch. The metronome was set beating to the second and ringing at every sixth beat. The writer began to learn or reproduce a list at a first ringing of the metronome; at the sixth ringing he stopped learning or reproducing the list. The stop watch was employed in order to stop each learning and each reproduction at the sixth ringing of the metronome. The stop watch was held within the field of vision. When learning, it was held next to a list, when reproducing it was held on the blank sheet of paper on which the writer wrote whatever he recalled of the list.

The procedure of experiment is reported in detail :

1. The list to be learned was placed blank side up on the table in the place indicated by the letter "P" in the diagrams.
2. The writer prepared to learn the list.
3. At a first ringing of the metronome, the list was turned right side up; at the same time, the stop watch which was held in the left hand was started. The writer began to learn the list as soon as it was turned right side up.
4. At the sixth ringing of the metronome, the writer stopped the stop watch and stopped learning the list. The list was turned blank side up and was pushed to the right side of the table. A blank sheet of paper was placed in the original place occupied by the list. The time registered by the stop watch was recorded and as soon as it was recorded, the stop watch was reset at 0.
5. The writer waited for the metronome to ring again.
6. At the ringing of the metronome, the writer started the stop watch and began to write on the blank sheet of paper whatever he recalled of the list.

7. At the sixth ringing of the metronome the writing was stopped; the stop watch was also stopped. The sheet of paper on which the writer had been writing was turned blank side up and was pushed into the upper left hand corner of the table. The time registered by the stop watch was recorded; the stop watch was reset at 0. As soon as the stop watch was reset at 0, the memory list was replaced (blank side up) in its original place.

8. The writer waited for the metronome to ring again.

9. As soon as the metronome rang, the list was learned again as described in steps 3 and 4; it was reproduced as described in steps 5, 6 and 7.

The list was learned and reproduced alternately in the above manner until four correct reproductions were made in succession.

Procedure for learning lists aloud:

The procedure was the same as that involved when learning lists silently, the only difference being that in the present case the memory material was read aloud when learning it.

II. Procedure in Addition Problems

As already stated, in the group of lists of forty-five one place numbers and in the first group of lists of fifteen two place numbers, the lists marked 1 were also added while vocalizing the vowel "E," the lists marked 2 were added silently and the lists marked 3 were added aloud. In the second group of lists of fifteen two place numbers, the lists marked 1 were added while making expulsions of "Pe"; the lists marked 2 were added silently; the lists marked 3 were added aloud. In each group of lists, the numbers 1, 2, and 3 were written on the blank side of the lists. When ready for experimentation, a group of lists was taken from the envelope in which it was contained and was placed in a box large enough to contain the lists. The lists were placed in the box blank side up. Care was taken to see that the lists appeared in the rotating order of 1, 2, 3; 2, 3, 1; 3, 1, 2; 1, 2, 3; 2, 3, 1; 3, 1, 2; etc.

Prior to experimenting with the second group of lists of two place numbers, the writer practiced nine hundred times expiring two hundred and fifty cubic inches of air while making rapid expulsions of "Pe" at the pitch of three hundred and nine double vibrations. During the entire duration of each

series of expulsions, the tone of three hundred and nine double vibrations was given continuously by the Baglioni reed pedal organ. The two hundred and fifty cubic inches of air were inspired from the Bernardo wet spirometer after having made three full inspirations and three full expirations, the two hundred and fifty cubic inches of air being inspired immediately after the third expiration.

Procedure for adding lists while vocalizing the vowel "E":

The vocalization of the vowel "E" was made at the pitch of three hundred and nine double vibrations. The duration of the vocalization was determined by the time required to expire two hundred and fifty cubic inches of air inspired from the Bernardo wet spirometer. A stop watch was employed to measure the duration of the vocalization. During the entire vocalization of the vowel, the tone of three hundred and nine double vibrations was given continuously by the Baglioni reed pedal organ. The continuous sounding of the tone was made possible as described on page 27, when treating the procedure for learning lists while vocalizing the vowel "E."

Below is described in detail the procedure for adding a list while vocalizing the vowel:

1. The spirometer was set at two hundred and fifty cubic inches.
2. The list was taken from the box in which it was contained and was placed blank side up on the table in the place indicated by the letter "P" in the diagrams I and II.
3. The tone of three hundred and nine double vibrations was sounded continuously from this moment on.
4. Three full inspirations and three full expirations were made; at the end of the third expiration, the two hundred and fifty cubic inches of air were inspired from the spirometer.
5. Immediately after having inspired the two hundred and fifty cubic inches of air, the writer began to vocalize the vowel "E," started the stop watch which was held in his left hand and turned the list right side up. Upon having turned the list right side up, the writer began to add.
6. As soon as the two hundred and fifty cubic inches of air had been expired, the writer stopped the stop watch and stopped adding. The sum added and the time registered by the stop watch were recorded.

Procedure for adding lists while making expulsions of "Pe":

The procedure for adding lists while making expulsions of "Pe" was the same as the procedure involved when adding lists while vocalizing the vowel "E." In the present case, instead of vocalizing the vowel "E," a continuous series of rapid expulsions of "Pe" was made while adding the lists. As in the case of adding lists while vocalizing the vowel "E," the duration of the series of expulsions of "Pe" was determined by the time required to expire two hundred and fifty cubic inches of air inspired from the Bernardo wet spirometer. In addition, it must be remembered (see page 31) that before experimenting with the present lists as well as with other lists of the same group, the writer practiced nine hundred times expiring two hundred and fifty cubic inches of air while making expulsions of "Pe" at the pitch of three hundred and nine double vibrations.

Procedure for adding lists silently:

Each list was exposed for thirty seconds if it belong to a group in which the lists marked 1 were added while vocalizing the vowel "E"; it was exposed for eighteen seconds if it belonged to the group in which the lists marked 1 were added while making expulsions of "Pe." The time was controlled by a metronome and a stop watch. The metronome was set beating to the second and ringing at every sixth beat. At a first ringing of the metronome, the experimenter began to add a list of numbers; at the sixth ringing he stopped adding. The stop watch was employed in order to stop the adding at the sixth ringing of the metronome. It was held next to the list so as to be located within the field of vision.

Below is given the procedure of experiment in detail:

1. The list was taken from the box in which it was contained and was placed blank side up on the table.
2. The writer prepared to turn the list right side up.
3. At the first ringing of the metronome, the list was turned right side up; the stop watch which was held in the left hand was started. The writer began to add as soon as the list was turned right side up.
4. At the sixth ringing of the metronome, the stop watch was stopped; the adding was also stopped. The sum added and the time registered by the stop watch was recorded.

Procedure for adding lists aloud:

The procedure was the same as that involved when adding lists silently, in the present case the only difference being that the numbers were added aloud. Each list was exposed for thirty seconds if it belonged to a group in which the lists marked 1 were added while vocalizing the vowel "E"; each list was exposed for eighteen seconds if it belonged to the group in which the lists marked 1 were added while making expulsions of "Pe."

B. Procedures of Experimentation Involved With Other Subjects

Preparatory to experimentation, each subject was requested to expire a fixed volume of air fifteen to twenty times while vocalizing the vowel "E." The air was inspired from the standard wet spirometer. The amount inspired represented approximately the maximum amount that the subject could inspire from the spirometer. Care was taken to fix this amount carefully so that with each inspiration the subject inspired the entire amount. For some subjects, the amount inspired was fixed as low as one hundred and fifty cubic inches; for others the amount inspired was fixed at higher levels, some subjects inspiring two hundred and fifty cubic inches of air. While expiring the fixed quantity of air, each subject vocalized the vowel "E" at a pitch most suitable for the vocalization. For all subjects considered as a group, the pitch at which the vowel was vocalized ranged from one hundred and seventy six double vibrations to three hundred and forty double vibrations. All subjects made three full inspirations and three full expirations before inspiring the air from the spirometer, the air being inspired immediately after the third expiration. A tone most suitable for the vocalization of the vowel "E" was given continuously by the Ellis reed pedal organ before and during the entire expiration of the air inspired from the spirometer. The organ was operated by the writer.

1. Memory Problems

The reader will recall that in each group of memory lists submitted to a group of twelve subjects,³ the lists were marked 1 and 2. The reader will also recall that the lists marked 1

³ First group of subjects.

were learned while vocalizing the vowel "E" and that the lists marked 2 were learned silently. The numerals 1 and 2 were written on the blank side of the lists. When submitted to the subjects, the lists were presented blank side up in the rotating order of 1, 2; 2, 1; 1, 2.

The subjects were instructed verbally how the lists should be learned. Before being presented, a group of lists, the subjects were instructed that a list bearing the numeral 1 on its blank side should be learned while vocalizing the vowel "E" and that a list having the numeral 2 on its blank side should be learned silently. Upon presenting a list, the writer always reminded the subjects of these instructions.

Procedure for learning lists while vocalizing the vowel "E":

The lists were learned while the subjects vocalized the vowel "E" at a pitch most suitable for the vocalization. The duration of the vocalization was determined by the time required to expire the fixed quantity of air inspired from the standard wet spirometer. The time was measured by the writer; a stop watch was employed.

The procedure for learning the lists is reported in detail:

1. The subject set the spirometer at the fixed level.
2. The writer placed a list blank side up on the table in the place indicated by the letter "P" in diagrams I and II.
3. The subject was instructed to prepare for the list. He was reminded that a list bearing the numeral 1 on its blank side should be learned while vocalizing the vowel "E."
4. The tone most suitable for the vocalization was sounded continuously from this moment until the list was finally learned.
5. The volume of air in the spirometer was inspired immediately after having made three full inspirations and three full expirations.
6. As soon as the air was inspired, the subject began to vocalize the vowel "E," at the same time he turned the list right side up. He began to learn the list as soon as it was turned right side up. The writer started the stop watch at the moment the subject began to vocalize the vowel.
7. After having expired the fixed volume of air, the subject turned the list blank side up and pushed it to the right side of the table. He reset the spirometer at the fixed level and placed a blank sheet of paper in the original place occupied by the list. The writer stopped the stop watch as soon as the subject

stopped vocalizing the vowel, i.e., when the air inspired from the spirometer had been expired. The time registered by the stop watch was recorded. The stop watch was reset at 0.

8. As soon as the blank sheet of paper was placed in the original place occupied by the list, the subject again inspired the fixed quantity of air from the spirometer immediately after having made three full inspirations and three full expirations.

9. Having inspired the air, the subject began to vocalize the vowel "E" and began to write on the blank sheet of paper whatever he recalled of the list. The writer started the stop watch as soon as the subject began to vocalize the vowel.

10. At the termination of the vocalization, i.e., after having expired the fixed quantity of air, the writer stopped the stop watch, the subject turned the sheet of paper on which he had been writing blank side up and pushed it into the upper left corner of the table. The subject reset the spirometer at the fixed level and replaced the memory list in its original place. In replacing the list in its original place, care was taken to keep it blank side up. The time registered by the stop watch was recorded. The stop watch was reset at 0.

11. The subject relearns the list as described in steps 5, 6 and 7, and reproduced it as described in steps 8, 9 and 10.

The list was learned and reproduced alternately as described above until four correct reproductions were made in succession.

Procedure for learning lists silently:

For each exposure of a list, the time was the same; for each reproduction of the list, the time was also the same. The time for exposing a list was determined by the longest time that was required to expire the air inspired from the spirometer when learning the preceding list of the same group while vocalizing the vowel "E." Similarly, the time for reproducing the list was determined by the longest time that was required to expire the same fixed quantity of air inspired from the spirometer when reproducing the preceding list while vocalizing the vowel.⁴ The time was controlled by the writer by means of a stop watch.

⁴ Let us suppose that in learning a list marked 1 of a certain group of memory lists, the longest time required to expire the fixed quantity of air inspired from the spirometer was thirty seconds while vocalizing the vowel "E"; let us also suppose that in reproducing the list while vocalizing the vowel "E," the longest time required to expire the air inspired from the spirometer was thirty-five seconds. When the next list was presented, i.e., the list marked 2 which the subject was instructed to learn silently, each exposure of the list was limited to thirty seconds whereas each reproduction was limited to thirty-five seconds.

Below is reported in detail the procedure of experiment:

1. The writer placed a list blank side up on the table.
2. The subject was instructed to prepare for the list. He was reminded that a list bearing the numeral 2 on its blank side should be learned silently.
3. At the signal now, the writer started the stop watch; the subject turned the list right side up and began to learn it.
4. At the signal stop, the writer stopped the stop watch. The subject turned the list blank side up and pushed it to the right side of the table; in the original place occupied by the list he placed a blank sheet of paper. The stop watch was reset at 0.
5. The subject prepared to reproduce the list.
6. At the signal now, the subject began to write on the sheet of paper whatever he recalled of the list; at the same time, the writer started the stop watch.
7. At the signal stop, the stop watch was stopped. The subject stopped reproducing the list and turned the sheet of paper on which he had been writing blank side up. He pushed the paper into the upper left corner of the table and replaced the memory list in its original place. In replacing the list in its original place, care was taken to keep it blank side up.
8. The subject prepared to learn the list again according to steps 3 and 4.
9. The subject prepared to reproduce the list according to steps 6 and 7.

In the above manner, the list was learned and reproduced alternately until four correct reproductions were made in succession.

2. *Addition Problems*

As was the case with the groups of memory lists submitted to the first group of twelve subjects, the lists in each group of addition problems submitted to the second, third and fourth groups of subjects were marked 1 and 2, the lists marked 1 being added while vocalizing the vowel "E" and the lists marked 2 being added silently. The lists in each group were presented blank side up in the rotating order of 1, 2; 2, 1; 1, 2; 2, 1; 1, 2; etc. The numerals 1 and 2 were written on the blank side of the lists.

Before presenting a group of lists, the experimenter instructed subjects verbally that a list bearing the numeral 1 on its blank side should be added while vocalizing the vowel "E"

and that a list bearing the numeral 2 on its blank side should be added silently. The subject was always reminded of these instructions when a list was presented.

Procedure for adding lists while vocalizing the vowel "E":

The lists were added while vocalizing the vowel "E" at a pitch most suitable for the vocalization. The time required to expire the air inspired from the standard wet spirometer determined the duration of each vocalization. The tone most suitable for vocalizing the vowel was given continuously by the Ellis organ during the entire duration of a vocalization. The organ and the stop watch were operated by the writer.

The procedure of experiment is reported in detail:

1. The subject set the spirometer at the fixed level.
2. The writer placed a list blank side up on the table (in the place indicated by the letter "P" in the diagrams).
3. The subject prepared to add the list; he was reminded that a list bearing the numeral 1 on its blank side should be added while vocalizing the vowel "E."
4. The tone most suitable for the vocalization of the vowel was sounded continuously by the organ from this moment on.
5. The subject made three full inspirations, each inspiration being followed by a full expiration; immediately after the third expiration the air contained in the spirometer was inspired.
6. As soon as the air contained in the spirometer was inspired, the subject began to vocalize the vowel "E," turned the list right side up and began to add. The writer started the stop watch as soon as the subject began to vocalize the vowel.
7. The subject stopped adding as soon as the fixed quantity of air inspired from the spirometer had been expired; the stop watch was stopped as soon as the subject stopped vocalizing the vowel. The sum added and the time registered by the stop watch were recorded.

Procedure for adding lists silently:

The time for exposing a list was determined by the time that was required to expire the air contained in the spirometer, when adding the preceding list of the same group while vocalizing the vowel "E." The time was controlled by the writer by means of a stop watch.

The procedure of experiment is reported:

1. The writer placed a list blank side up on the table.
2. The subject prepared to learn the list; he was reminded that a list bearing the numeral 1 on its blank side should be added silently.
3. At the signal "now," the writer started the stop watch; the subject turned the list right side up and began to add.
4. At the signal "stop"; the subject stopped adding; the writer stopped the stop watch. The sum added and the time registered by the stop watch were recorded.

RESULTS

In the treatment of the results, those appertaining to four groups of forty subjects experimented upon are treated first; the results of experimentation upon the writer follow these. To be more explicit, we first treat the memory experiments upon the first group of 12 subjects and then we treat the memory experiments upon the writer. Following these, we treat in the same order the experiments in addition: that is we first treat the experiments in addition upon the second, third and fourth groups of subjects, and then the experiments in addition performed upon the writer.

I. MEMORY EXPERIMENTS

A. *Experiments Performed upon the First Group of Subjects. (Twelve Subjects Experimented upon)*

TABLE IA.
NUMBER OF REPETITIONS OF FIVE FOUR PLACE NUMBERS.

	<i>With Vocalization</i>	<i>Silently</i>
Average	6.139	6.528
σ	1.519	2.26
V	24.8	34.7
σ (Av.)	0.2131	0.3766

TABLE IB.
DIFFERENCES AND RELIABILITIES.

D	—0.389
σ (Dif.)	0.433
D/ σ (Dif.)	0.898

TABLE IIa.
REPETITION OF TWELVE NONSENSE SYLLABLES.

	<i>With Vocalization</i>	<i>Silently</i>
Average	14.833	15.33
σ	4.942	5.73
V	33.2	37.0
σ (Av.)	0.8236	0.955

TABLE IIb.
DIFFERENCES AND RELIABILITIES.

D	—0.5
σ (Dif.)	1.265
D/ σ (Dif.)	0.398

TABLE IIIa.
REPETITIONS OF TWELVE FOUR PLACE NUMBERS.

	<i>With Vocalization</i>	<i>Silently</i>
Average	20.775	19.525
σ	5.067	10.127
V	24.4	52.000
σ (Av.)	0.8445	1.688

TABLE IIIb.
DIFFERENCES AND RELIABILITIES.

D	1.250
σ (dif.)	1.887
D/ σ (dif.)	0.662

SUPPLEMENTARY STATISTICS

1. 5 subjects took more trials in 5 combinations of digits when they vocalized "E"; 3 subjects in nonsense work and 6 subjects in 12 combinations of digits.

2. 5 subjects took more trials without distraction in 5 combinations of digits; 7 subjects in nonsense work and 5 subjects in 12 combinations of digits.

3. 2 subjects in 5 combinations of digits; 2 in nonsense work, and 1 in 12 combinations of digits took an equal number of trials.

TABLE IV.
REPETITIONS FOR THE MEMORIZATION OF FIVE COMBINATIONS OF DIGITS.

<i>Subject</i>	<i>Average with Vocalization</i>	<i>Average without Vocalization (Silently)</i>	<i>Difference</i>
I	4.6	4.6	0.0
II	3.6	3.3	0.3
III	4.6	4.6	0.0
IV	5.0	7.3	—2.3
V	5.3	5.6	—0.3
VI	7.0	4.6	2.4
VII	5.6	6.0	—0.4
VIII	7.3	6.3	1.0
IX	6.6	10.0	—3.4
X	5.3	6.6	—1.3
XI	8.3	11.3	—3.0
XII	10.0	7.6	2.4

TABLE V.
REPETITIONS FOR THE MEMORIZATION OF TWELVE COMBINATIONS OF DIGITS.

<i>Subject</i>	<i>Average with Vocalization</i>	<i>Average without Vocalization (Silently)</i>	<i>Difference</i>
I	14.3	13.6	0.7
II	12.3	12.3	0.0
III	15.0	18.6	—3.6
IV	17.3	24.0	—6.7
V	22.0	21.0	1.0
VI	30.3	21.0	9.3
VII	18.6	21.6	—3.0
VIII	20.3	15.0	5.3
IX	21.0	29.6	—8.6
X	27.6	29.0	—1.4
XI	23.6	27.6	—4.0
XII	26.6	21.6	5.0

TABLE VI.
REPETITIONS FOR THE MEMORIZATION OF TWELVE NONSENSE SYLLABLES.

<i>Subject</i>	<i>Average with Vocalization</i>	<i>Average without Vocalization (Silently)</i>	<i>Difference</i>
I	9.0	8.6	0.4
II	9.0	9.0	0.0
III	11.3	12.3	—1.0
IV	13.0	15.0	—2.0
V	14.6	14.6	0.0
VI	20.6	14.6	6.0
VII	11.0	15.3	—4.3
VIII	14.0	11.6	2.4
IX	16.3	23.0	—6.7
X	21.0	20.6	0.4
XI	18.0	23.3	—5.3
XII	20.0	15.6	4.4

B. Experiments Performed upon the Writer as Subject

TABLE VIIA.

REPETITION OF FIVE NONSENSE SYLLABLES.

	<i>With Vocalization</i>	<i>Silently</i>	<i>Aloud</i>
Average	5.3	5.6	6.6
σ	0.471	0.471	0.471
V	8.650	8.150	6.920
σ (Av.)	0.272	0.272	0.272

TABLE VIIb.

DIFFERENCES AND THEIR RELIABILITIES.

	<i>With Vocalization vs. Silently</i>	<i>With Vocalization vs. Aloud</i>	<i>Silently vs. Aloud</i>
D	—0.33	—1.33	—1.0
σ (dif.)	0.385	0.385	0.385
D/ σ (dif.)	0.865	3.42	2.6

TABLE VIIIA.

REPETITION OF FIVE COMBINATIONS OF MUTE AND SEMI-CONSONANTS.

	<i>With Vocalization</i>	<i>Silently</i>	<i>Aloud</i>
Average	7.6	9.6	11.6
σ	1.634	0.471	1.249
V	21.1	4.87	10.7
σ (Av.)	0.942	0.272	0.72

TABLE VIIb.

DIFFERENCES AND THEIR RELIABILITIES.

	<i>With Vocalization vs. Silently</i>	<i>With Vocalization vs. Aloud</i>	<i>Silently vs. Aloud</i>
D	—2.0	—4.0	—2.0
σ (dif.)	0.98	1.19	0.77
D/ σ (dif.)	2.4	3.36	2.6

TABLE IXA.
NUMBER OF REPETITIONS FOR FIVE FOUR PLACE NUMBERS.

	<i>With Vocalization</i>	<i>Silently</i>	<i>Aloud</i>
Average	8.33	11.88	12.33
σ	1.49	2.625	1.74
V	17.95	22.2	13.78
σ (Av.)	0.497	0.875	0.57

TABLE IXB.
DIFFERENCES AND THEIR RELIABILITIES.

	<i>With Vocalization vs. Silently</i>	<i>With Vocalization vs. Aloud</i>	<i>Silently vs. Aloud</i>
D	-3.55	-4.00	-0.4
σ (dif.)	1.01	0.76	1.05
D/ σ (dif.)	3.465	5.26	0.381

Summary of Table IX

As seen from the table, vocalization increases the efficiency of memorization, reducing the number of repetitions by about one-third.

TABLE XA.
REPETITION OF LISTS OF TEN SHORT WORDS.

	<i>With Vocalization</i>	<i>Silently</i>	<i>Aloud</i>
Average	6.2	8.0	8.3
σ	1.353	1.245	1.414
V	22.8	15.6	17.0
σ (Av.)	0.451	0.415	0.471

TABLE XB.
DIFFERENCES AND THEIR RELIABILITIES.

	<i>With Vocalization vs. Silently</i>	<i>With Vocalization vs. Aloud</i>	<i>Silently vs. Aloud</i>
D	-1.7	-2.1	-0.3
σ (dif.)	0.613	0.651	0.627
D/ σ (dif.)	2.9	3.22	0.532

TABLE XIA.
REPETITION OF TWELVE NONSENSE SYLLABLES.

	<i>With Vocalization</i>	<i>Silently</i>	<i>Aloud</i>
Average	13.5	20.8	22.0
σ	1.58	2.559	2.449
V	11.6	12.25	11.1
σ (Av.)	0.527	0.853	0.816

TABLE XIB.
DIFFERENCES AND THEIR RELIABILITIES.

	<i>With Vocalization vs. Silently</i>	<i>With Vocalization vs. Aloud</i>	<i>Silently vs. Aloud</i>
D	-7.3	-8.4	1.11
σ (dif.)	1.0	0.97	1.18
D/ σ (dif.)	7.3	8.66	0.945

TABLE XIIA.
REPETITION OF TWELVE FOUR PLACE NUMBERS.

	<i>With Vocalization</i>	<i>Silently</i>	<i>Aloud</i>
Average	20.77	26.77	28.77
σ	1.473	3.39	2.394
V	7.35	12.7	8.32
σ (Av.)	0.491	1.13	0.798

TABLE XIIb.
DIFFERENCES AND THEIR RELIABILITIES.

	<i>With Vocalization vs. Silently</i>	<i>With Vocalization vs. Aloud</i>	<i>Silently vs. Aloud</i>
D	-6.0	-8.0	-2.0
σ (dif.)	1.14	0.813	1.38
D/ σ (dif.)	5.26	9.85	1.45

Summary of Table XII

As in the previous table, vocalization increases the efficiency of memorization.

Summary for the Memorization With Writer as Subject

In all six series of experiments on memorization, the efficiency is greater with vocalization. In two series, however, the differences are not sufficiently reliable; in both of these series only three lists were memorized.

II. ADDITION EXPERIMENTS

A. Experiments Performed upon Second Group of Twelve Subjects

TABLE XIIIa.
⁵ADDITION LISTS OF FORTY-FIVE ONE PLACE NUMBERS.
(Eleven Subjects Experimented Upon.)

	<i>Error</i>		<i>Amount</i>	
	<i>With</i> <i>Vocalization</i>	<i>Silently*</i>	<i>With</i> <i>Vocalization</i>	<i>Silently</i>
Average	0.4	0.22	29.69	28.009
σ	0.8775	0.6	7.07	7.457
V	219.9	270	23.8	26.55
σ (Av.)	0.118	0.081	0.955	1.00

* Number of errors for all lists: With vocalization 10.0; without 5.0.

⁵ The magnitude of the error was taken to be the difference between the sum obtained by the subject and the nearest true sum.

TABLE XIIIb.
DIFFERENCES AND THEIR RELIABILITIES.

	<i>Error</i>	<i>Amount</i>
D	+0.178	1.681
σ (dif.)	0.143	1.383
D/ σ (dif.)	1.246	1.22

TABLE XIVA.
ADDITION LISTS OF TWO PLACE NUMBERS.
(Twelve Subjects Experimented Upon.)

	<i>Error*</i>		<i>Amount</i>	
	<i>With</i> <i>Vocalization</i>	<i>Silently</i>	<i>With</i> <i>Vocalization</i>	<i>Silently</i>
Average	2.65	2.1616	10.166	9.6166
σ	6.24	5.0	3.652	3.39
V	238.0	231.0	35.9	35.2
σ (Av.)	0.805	0.645	0.47	0.4385

* Number of errors for all lists: With vocalization: 18.0; without 12.0.

TABLE XIVb.
DIFFERENCES AND THEIR RELIABILITIES.

	Error	Amount
D	0.49	0.55
σ (dif.)	1.03	0.603
D/ σ (dif.)	0.4754	0.91

Summary of Tables XIII and XIV

As seen from these tables, the differences between vocalization and no vocalization in adding one and two place numbers, are not reliable. The efficiency is, however, on the whole greater with vocalization.

SUPPLEMENTARY STATISTICS

TABLE XV.
ADDITION OF ONE PLACE NUMBERS.

Subject	With Distraction			Without Distraction		
	Average Error	Average Amount	Error Per Number Added	Average Error	Average Amount	Error Per Number Added
I	0.8	29.7	0.0269	0.4	30.8	0.013
II	0.0	39.6	—	0.0	31.4	—
III	0.0	42.0	—	0.0	43.0	—
IV	0.0	36.0	—	0.0	31.4	—
V	0.0	32.0	—	0.0	23.8	—
VI	0.0	29.2	—	0.0	22.6	—
VII	0.2	36.2	0.055	0.0	28.4	—
VIII	1.8	19.5	0.092	0.8	22.0	0.036
IX	1.4	15.4	0.091	0.4	23.2	0.01725
X	0.2	13.6	0.0147	0.2	17.4	0.0115
XI	0.0	33.6	—	0.6	34.0	0.465

TABLE XVI.
ADDITION—TWO PLACE NUMBERS.

Subject	With Distraction			Without Distraction		
	Average Error	Average Amount	Error Per Number Added	Average Error	Average Amount	Error Per Number Added
I	5.2	12.8	0.41	9.0	11.8	0.76
II	0.0	14.6	—	0.0	11.2	—
III	0.0	13.8	—	0.0	14.0	—
IV	0.0	36.0	—	0.0	31.4	—
V	0.4	12.2	0.0328	4.8	9.6	0.5
VI	0.0	11.2	—	0.0	9.0	—
VII	0.0	11.6	—	0.0	10.0	—
VIII	6.2	5.8	1.07	0.0	6.8	—
IX	2.2	4.0	0.55	1.4	6.0	0.2334
X	2.4	4.4	0.545	2.6	4.8	0.542
XI	0.0	33.6	—	0.6	34.0	0.1765
XII	11.8	6.8	1.735	4.6	8.4	0.547

SUPPLEMENTARY STATISTICS

TABLE XVII.

ONE PLACE NUMBERS.		TWO PLACE NUMBERS.	
5 Subjects:	no errors with or without vocalization	5 Subjects:	no errors with or without vocalization
1 Subject:	errors with vocalization, none without	1 Subject:	errors with vocalization, none without
1 Subject:	errors without vocalization, none with	6 Subjects:	errors under both conditions
4 Subjects:	errors under both conditions		
3 Subjects:	errors larger with vocalization	2 Subjects:	errors larger with vocalization
3 Subjects:	errors larger without vocalization	4 Subjects:	errors larger without vocalization
1 Subject:	errors equal with or without vocalization	2 Subjects:	more errors with vocalization
2 Subjects:	more errors with vocalization	2 Subjects:	equal number of errors under both conditions
2 Subjects:	equal number of errors under both conditions	2 Subjects:	more errors without
5 Subjects:	added a greater amount with vocalization	6 Subjects:	added a greater amount with vocalization
6 Subjects:	added a greater amount without vocalization	6 Subjects:	added a greater amount without vocalization

B. Experiments Performed upon Third and Fourth Groups of Subjects; Eight Subjects Experimented upon in Each Group, Each Subject Being Given Three Sets of Sixty Addition Problems.⁶ Thirty of the Problems in Each Set Were Performed With Vocalization of "E" and Thirty Without

Tables XVIII to XXVII inclusive treat according to subject the amount or quantity (i.e., the number of numbers added) when adding lists. (Each entry in these tables is an average of thirty trials since in each set thirty problems were performed with the vocalization of "E" and thirty without.)

⁶Each set of problems was done in a sitting of about one and one-half hours on a single day.

TABLE XVIII.
ONE PLACE NUMBERS, THIRD GROUP OF SUBJECTS.
Averages and σ 's for Sums Added.

Subject	First Set				Second Set				Third Set			
	With "E"		Without "E"		With "E"		Without "E"		With "E"		Without "E"	
	Av.	σ	Av.	σ	Av.	σ	Av.	σ	Av.	σ	Av.	σ
1	13.2666	1.2806	11.9666	1.1211	22.0000	2.0639	17.5666	1.2713	24.4000	3.1480	20.3000	2.1931
2	19.6666	3.1968	18.7000	3.1843	23.7666	2.7964	19.7000	2.8425	23.6000	2.7404	18.4000	2.4839
3	30.7000	1.5099	26.0666	1.8330	38.0000	2.6324	30.9000	2.2271	30.2000	3.4684	25.0333	3.8301
4	34.0666	2.4979	30.1000	3.7629	43.3000	2.5317	35.0333	2.8757	44.7666	.4228	41.6000	2.6400
5	16.0333	3.6891	14.1666	2.8600	18.5000	2.8495	13.4666	2.6888	15.3666	3.4727	11.8333	2.1794
6	10.6000	2.2293	9.3000	2.1307	15.6000	2.4718	11.2333	2.1095	14.2333	2.4637	10.4333	1.4071
7	12.4666	1.3304	12.5000	1.3341	17.4666	1.1560	13.2000	1.8867	20.1333	3.4234	15.8666	2.7586
8	35.8333	3.7027	35.2000	3.4000	38.2000	4.0286	32.1666	4.0323	37.3333	3.2664	32.9000	2.9866

TABLE XX.
ONE PLACE NUMBERS.
Relative Variabilities for Sums Added.

Subject	First Set			Second Set			Third Set		
	<i>V</i> (Coef. of Variability) With "E"	<i>V</i> ¹ (Coef. of Variability) Without "E"	<i>V</i> (Coef. of Variability) of <i>V</i> in Terms of <i>V</i> ¹	<i>V</i> (Coef. of Variability) With "E"	<i>V</i> ¹ (Coef. of Variability) Without "E"	<i>V</i> (Coef. of Variability) of <i>V</i> in Terms of <i>V</i> ¹	<i>V</i> (Coef. of Variability) With "E"	<i>V</i> ¹ (Coef. of Variability) Without "E"	<i>V</i> (Coef. of Variability) of <i>V</i> in Terms of <i>V</i> ¹
1	9.6528	15.2950	.6311	9.3813	13.5427	.6927	12.9016	10.8034	1.1942
2	16.2549	17.0285	.9546	11.7600	14.4289	.8154	11.6118	13.4994	.8602
3	4.9182	7.0319	.6994	6.9273	7.2074	.9611	11.4847	15.3000	.7506
4	7.3324	12.5013	.5865	5.8468	8.2085	.7123	.9445	6.3461	.1488
5	23.0089	20.1883	1.1397	15.4027	19.9664	.7714	22.5990	18.4175	1.2270
6	21.0311	22.9100	.9180	15.8448	18.7789	.8438	17.3094	13.4886	1.2833
7	10.6717	10.6728	.9999	6.6183	14.2931	.4630	17.0036	17.3862	.9780
8	10.3332	9.6590	1.0698	10.5460	12.5356	.8413	8.7493	9.0778	.9638

TABLE XXI.
TWO PLACE NUMBERS.
Relative Variability for Sums Added.

Subject	First Set			Second Set			Third Set		
	<i>V</i> (Coef. of Variability) With "E"	<i>V</i> ¹ (Coef. of Variability) Without "E"	Variability of <i>V</i> in Terms of <i>V</i> ¹	<i>V</i> (Coef. of Variability) With "E"	<i>V</i> ¹ (Coef. of Variability) Without "E"	Variability of <i>V</i> in Terms of <i>V</i> ¹	<i>V</i> (Coef. of Variability) With "E"	<i>V</i> ¹ (Coef. of Variability) Without "E"	Variability of <i>V</i> in Terms of <i>V</i> ¹
1	11.8800	12.0411	.9866	8.4233	12.8462	.6557	17.8465	16.1046	1.1082
2	25.1691	21.7720	1.1560	21.7480	16.8602	1.2899	14.1621	17.5730	.8059
3	14.3056	17.1290	.8350	9.6245	15.4100	.6246	12.7628	12.6716	1.0072
4	20.1147	25.0724	.8023	14.1061	16.2660	.8672	15.8016	14.8148	1.0666
5	18.6813	18.4449	1.0128	8.9599	11.8399	.7568	9.6277	15.8576	.6071
6	13.2262	12.0703	1.0958	14.0484	10.7563	1.3061	14.7392	12.7659	1.1546
7	16.8758	12.9565	1.3025	11.0728	15.3434	.7217	13.1553	12.8555	1.0233
8	12.9768	14.0209	.9255	9.2298	8.5590	1.0784	10.2445	10.2728	.9972

TABLE XXII.
ONE PLACE NUMBERS.
Diff., σ Diff., $\frac{D}{\sigma}$ Diff. Between the Conditions of Vocalization and Non Vocalization, i.e., With "E" and Without "E."

Subject	First Set				Second Set				Third Set			
	Diff.	σ Diff.	$\frac{D}{\sigma}$ Diff.	Diff.	σ Diff.	$\frac{D}{\sigma}$ Diff.	Diff.	σ Diff.	$\frac{D}{\sigma}$ Diff.	σ Diff.	$\frac{D}{\sigma}$ Diff.	σ Diff.
1	1.3000	.4079	3.1870	4.4334	.5750	7.7102	4.1000	.7004	5.8537			
2	.9666	.8238	1.1733	4.0666	.7281	5.5852	5.2000	.6753	7.7002			
3	4.6334	.4336	10.6858	7.1000	.6295	11.2787	5.1667	.9434	5.4766			
4	3.9666	.8246	4.8103	8.2667	.6995	11.8180	3.1666	.4882	6.4862			
5	1.8667	.8522	2.1904	5.0334	.7153	7.0367	3.5333	.7485	4.7205			
6	1.3000	.5629	2.3094	4.3667	.5933	7.3600	3.8000	.5180	7.3359			
7	— .0334 ¹	.3439	.0971	4.2666	.4040	10.5608	4.2667	.8027	5.3154			
8	.6333	.9178	.6897	6.0334	1.039	5.8069	4.4333	.8081	5.4857			

¹ With "E"—Without "E."

TABLE XXIII.
TWO PLACE NUMBERS.
Diff., σ Diff., $\frac{D}{\sigma}$ Diff. Between the Conditions of Vocalization and Non Vocalization, i.e., With "E" and Without "E."

Subject	First Set			Second Set			Third Set		
	Diff.	σ Diff.	$\frac{D}{\sigma}$ Diff.	Diff.	σ Diff.	$\frac{D}{\sigma}$ Diff.	Diff.	σ Diff.	$\frac{D}{\sigma}$ Diff.
1	2.5667	.2604	9.8567	3.2667	.2296	14.2277	1.6667	.4004	4.1625
2	.5333	.2802	1.9033	1.4334	.2816	5.0901	1.0000	.1889	5.2938
3	1.8333	.3521	5.2067	3.1667	.3194	9.9145	2.2334	.3366	6.6351
4	.8000	.3087	2.5915	1.3666	.2330	5.8652	.8000	.2611	3.4617
5	2.2000	.3878	5.6730	3.6000	.2933	12.2741	4.0334	.3692	10.9247
6	1.0666	.2844	3.7503	1.8333	.3046	6.0187	1.0666	.3269	2.9885
7	1.5333	.3495	3.9365	3.4000	.3715	9.1520	2.1666	.3715	5.8320
8	1.4000	.3061	4.5736	2.9667	.2558	11.5977	1.8000	.2685	6.7039

It is apparent from these tables (XVIII, XIX) that in this prolonged experiment the output with "E" (while vocalizing the vowel "E") is definitely superior to the output without "E"; the superiority is consistent from set to set and with single exception⁷ from individual to individual.

As to the (absolute) variabilities, given in the columns of σ , there is a slight tendency for them to be greater when the vowel "E" was sounded than without the vowel, but this could be expected from the larger averages with "E," and is best examined in terms of the relative variabilities in the next following tables.

From a cursory view of Table XX it is apparent that with one place numbers the variability with vocalization of the vowel "E" is generally smaller than the corresponding variability without the vocalization. With two place numbers (Table XXI) it also appears that the variability with vocalization of the vowel is somewhat smaller than the variability without the vocalization. With two place numbers the difference under the two conditions is not as marked as with the one place numbers.

From the $\frac{D}{\sigma \text{ diff.'s}}$ values of Tables XXII and XXIII it becomes apparent at once that the results showing greater output with vocalization of the vowel "E" are reliable. In most cases of the first set of one place numbers and in most cases of the first set of two place numbers the reliability of the greater output with "E" was either very good or excellent. In all cases of the second and third sets of one place numbers and in all cases of the second and third sets of two place numbers the reliability of the greater output with "E" was excellent.

As a further check on the reliability of the differences obtained in favor of the performance of the adding task while vocalizing the vowel "E," the original records were again examined pair by pair. In the experiment, each performance with "E" was paired with an immediately following performance without "E." The score of numbers added with "E" was now divided by the paired score without "E," and a ratio thus obtained which was greater than 1 in case the performance with "E" had exceeded that without "E," and less than 1 in the opposite case. There were 30 pairs, and 30 ratios in each set for each individual; and the average of each set of 30 ratios is given in the tables that follow.

⁷ Seventh subject—Table XVIII, Set I.

TABLE XXIV.

ONE PLACE NUMBERS.

Averages, σ 's, σ_{AV} 's of Ratios of Sums Added Under the Two Conditions, i.e., with "E" and Without "E": Ratios Determined by Dividing Sums Added With "E" by Sums Added Without "E" in Order to Determine the Former in Terms of the Latter.*

Subject	First Set			Second Set			Third Set		
	<i>Av.</i>	σ	σ_{AV}	<i>Av.</i>	σ	σ_{AV}	<i>Av.</i>	σ	σ_{AV}
1	1.1211	.2066	.0377	1.2713	.1546	.0282	1.2211	.2466	.0450
2	1.0794	.1863	.0340	1.2072	.1808	.0330	1.2924	.2283	.0417
3	1.1821	.0889	.0162	1.2341	.1077	.0197	1.2254	.1364	.0249
4	1.1443	.1249	.0228	1.2395	.0639	.0117	1.0805	.0831	.0152
5	1.1538	.2687	.0496	1.3925	.1572	.0287	1.2885	.3593	.0656
6	1.2053	.3995	.0723	1.4305	.2960	.0540	1.3855	.2961	.0541
7	1.0094	.1612	.0294	1.3486	.2186	.0399	1.2536	.3493	.0638
8	1.0216	.0873	.0159	1.2052	.1241	.0227	1.1386	.0790	.0144

* The sum added for any given list while vocalizing the vowel "E" was divided by the sum for the corresponding list when not vocalizing the vowel.

TABLE XXV.
TWO PLACE NUMBERS.

Averages, σ 's, σ_{AV} 's of Ratios of Sums Added under the Two Conditions, i.e., with "E" and without "E" and without "E": Ratios Computed by Dividing Sums Added with "E" by Sums Added without "E" in Order to Determine the Former in Terms of the Latter.¹

Subject	First Set			Second Set			Third Set		
	Av.	σ	σ_{AV}	Av.	σ	σ_{AV}	Av.	σ	σ_{AV}
1	1.3782	.2927	.0534	1.4809	.1221	.0229	1.2088	.1345	.0246
2	1.1482	.2973	.0543	1.3394	.3766	.0688	1.2854	.2735	.0499
3	1.2658	.1881	.0343	1.4035	.2753	.0503	1.2703	.2020	.0369
4	1.2000	.2518	.0460	1.2759	.1868	.0341	1.1629	.1895	.0346
5	1.3605	.2890	.0528	1.4055	.2207	.0403	1.4436	.2202	.0402
6	1.1469	.1114	.0203	1.2274	.1603	.0293	1.1235	.1729	.0316
7	1.1977	.2189	.0400	1.3801	.1949	.0356	1.2418	.2086	.0381
8	1.1860	.1903	.0347	1.3201	.1308	.0239	1.2080	.1691	.0309

Tables XXIV and XXV again confirm the previous finding that (in a prolonged experiment of this sort) the vocalization period is consistently superior to the corresponding non-vocalization period in amount of work done. The ratios are above 1 for every set and for every subject, and in nearly every case they are reliably greater than 1, as can be seen if the excess of each ratio above 1 is divided by the corresponding σ_{Av} .

It will be seen that the ratio is always greater in Set 2 than in Set 1, for the same subject. That is to say, the relative advantage of the performance with vocalization of "E" increased with practice. It did not increase indefinitely, however, since the ratios in Set 3, while usually greater than those in Set 1, are also usually less than in Set 2.

From an analysis of the results of Tables XXVI and XXVII we may conclude (1) that with one place numbers the superiority of the vocalization periods for quantitative output is not only maintained from the first to the second sets of problems but that this advantage is increased in the second set as the high values of the $\frac{D}{\sigma}$ diff's indicate, (2) that no such progress holds between the second and third sets of problems, (3) that in most cases the third set is superior to the first set for output during the vocalization periods and that this superiority is reliable. With two place numbers we may also conclude (1) that the superiority of the amount of work done while vocalizing the vowel "E" is not only maintained from the first to the second sets but that it is increased in the second set and (2) that no such progress holds between the second and third sets of problems. Between the first and third sets of two place numbers we may state that there is no definite tendency for the amount of work done during the vocalization periods to be superior from one set to the other—either way, *i.e.*, from the first to the third or from the third to the first.

Tables XXVIII to XXXI, inclusive, present the quantitative data (*i.e.*, amount of numbers added when adding lists) as group results. Tables XXVIII and XXX present the group results for one place numbers given to the third group of subjects; Tables XXIX and XXXI present the group results for two place numbers given to the fourth group of subjects.

TABLE XXVI.
ONE PLACE NUMBERS.
 $\frac{\nu}{\sigma}$ Diff. Between Ratios of Quantities.

Subject	Diff., σ Diff., $\frac{\nu}{\sigma}$ Diff. Between Ratios of First and Second Sets of Problems—Comparison Always in the Direction of Second Set Minus First Set				Diff., σ Diff., $\frac{\nu}{\sigma}$ Diff. Between Ratios of Second and Third Sets of Problems—Comparison Always in the Direction of Second Set Minus Third Set				Diff., σ Diff., $\frac{\nu}{\sigma}$ Diff. Between Ratios of First and Third Sets of Problems—Comparison Always in the Direction of Third Set Minus First Set			
	Diff.	σ Diff.	$\frac{\nu}{\sigma}$ Diff.	$\frac{\nu}{\sigma}$ Diff.	Diff.	σ Diff.	$\frac{\nu}{\sigma}$ Diff.	$\frac{\nu}{\sigma}$ Diff.	Diff.	σ Diff.	$\frac{\nu}{\sigma}$ Diff.	$\frac{\nu}{\sigma}$ Diff.
1	.1502	.0471	3.1876	3.1876	.0502	.0531	.9447	.9447	.1000	.0587	1.7024	1.7024
2	.1278	.0474	2.6967	2.6967	— .0852	.0532	1.6027	1.6027	.2130	.0538	3.9598	3.9598
3	.0519	.0255	2.0365	2.0365	.0086	.0326	.2650	.2650	.0433	.02971	1.4574	1.4574
4	.0952	.0256	3.7173	3.7173	.1590	.0191	8.3112	8.3112	— .0638	.0274	2.3293	2.3293
5	.2387	.0573	4.1672	4.1672	.1040	.0716	1.4525	1.4525	.1347	.0822	1.6380	1.6380
6	.2252	.0908	2.4807	2.4807	.0450	.0764	.5887	.5887	.1802	.0908	1.9848	1.9848
7	.3392	.0496	6.8406	6.8406	.0950	.0752	1.2632	1.2632	.2442	.0724	3.3729	3.3729
8	.1836	.0277	6.6268	6.6268	.0666	.0269	2.4775	2.4775	.1171	.0215	5.4471	5.4471

TABLE XXVII.
TWO PLACE NUMBERS.
Diff., σ Diff., $\frac{D}{\sigma}$ Diff. Between Ratios of Quantities.

Subject	Ratios of First and Second Sets of Problems—Comparison Always in the Direction of Second Set Minus First Set			Ratios of Second and Third Sets of Problems—Comparison Always in the Direction of Second Set Minus Third Set			Ratios of Third and First Sets of Problems—Comparison Always in the Direction of Third Set Minus First Set		
	Diff.	σ Diff.	$\frac{D}{\sigma}$ Diff.	Diff.	σ Diff.	$\frac{D}{\sigma}$ Diff.	Diff.	σ Diff.	$\frac{D}{\sigma}$ Diff.
1	.1027	.0579	1.7734	.2721	.0332	8.2031	— .1694	.0588	2.8804
2	.1912	.0876	2.1826	.0540	.0850	.6354	.1372	.0738	1.8603
3	.1377	.0609	2.2621	.1332	.0623	2.1366	.0045	.0504	.0893
4	.0759	.0572	1.3246	.1130	.0486	2.3265	— .0371	.0575	.6449
5	.0450	.0664	.6779	— .0381	.0569	.6695	.0831	.0663	1.2528
6	.0805	.0356	2.2587	.1039	.0431	2.4134	— .0234	.0376	.6232
7	.1824	.0535	3.4080	.1383	.0521	2.6534	.0441	.0552	.7988
8	.1341	.0422	3.1814	.1121	.0390	2.8721	.0220	.0465	.4734

List	First Set		Second Set		Third Set	
	With "E"	Without "E"	With "E"	Without "E"	With "E"	Without "E"
1	20.3750	20.1250	26.2500	21.7500	26.2500	20.6250
2	23.5000	21.5000	26.5000	21.7500	24.7500	22.2500
3	21.1250	20.5000	25.3750	22.2500	26.7500	21.6250
4	22.5000	20.5000	25.5000	21.7500	26.6250	23.0000
5	23.2500	20.0000	26.3750	23.2500	25.3750	21.2500
6	21.0000	19.2500	26.5000	21.8750	25.7500	22.7500
7	22.3750	20.5000	27.6250	22.1250	25.8750	21.7500
8	22.1250	19.2500	25.2500	19.8750	26.1250	22.5000
9	21.2500	18.7500	28.1250	20.5000	26.3750	21.6250
10	22.1250	19.8750	28.3750	21.6250	25.7500	22.7500
11	21.6250	20.0000	27.0000	20.6250	25.8750	20.7500
12	20.2500	19.1250	26.0000	21.5000	25.6250	22.3750
13	22.2500	20.5000	26.7500	22.0000	26.5000	21.7500
14	20.3750	18.7500	25.7500	21.5000	27.1250	23.1250
15	19.6250	18.3750	26.6250	22.1250	26.1250	22.8750
16	21.0000	20.6250	27.1250	19.6250	26.6250	22.0000
17	21.7500	18.8750	27.8750	22.2500	26.1250	22.1250
18	20.7500	20.6250	28.6250	21.8750	25.7500	20.8750
19	20.1250	18.3750	27.7500	20.8750	26.7500	22.8750
20	21.1250	20.0000	27.1250	21.3750	26.0000	20.3750
21	21.7500	20.0000	27.2500	23.2500	26.0000	22.1250
22	22.7500	21.7500	26.3750	20.8750	24.7500	19.7500
23	22.5000	18.8750	27.5000	21.6250	26.8750	22.8750
24	21.8750	20.6250	28.5000	21.7500	27.8750	23.0000
25	21.1250	18.8750	28.1250	21.6250	26.8750	23.8750
26	21.2500	18.2500	28.1250	23.2500	25.7500	23.2500
27	21.6250	19.3750	27.2500	22.3750	26.8750	22.1250
28	21.1250	18.8750	27.6250	22.3750	26.8750	21.0000
29	23.3750	19.0000	28.1250	21.5000	27.1250	21.0000
30	21.5000	19.3750	28.6250	21.6250	26.1250	21.8750
Total	647.3750	592.5000	813.1250	649.7500	786.3750	661.3750
Av.	21.5791	19.7500	27.1041	21.6583	26.2125	22.0458
σ	.9955	1.0440	.5456	.8744	.8520	.8977
Coef. V.	4.6133	5.2860	2.0130	4.0373	3.2504	4.0720
σ_{AV}	.1818	.19060	.0996	.1596	.1555	.16390
	σ Diff.	.2634	σ Diff.	.1881	σ Diff.	.2261
	Diff.	1.8291	Diff.	5.4458	Diff.	4.1667
	$\frac{D}{\sigma}$ Diff.	6.9441	$\frac{D}{\sigma}$ Diff.	28.9516	$\frac{D}{\sigma}$ Diff.	18.4285
Relative Variability of Av's With "E" in Terms of Av's Without "E"						
	First Set	Second Set	Third Set			
	.8727	.4986	.7982			

In these tables (XXVIII and XXIX) we have treated statistically according to group the average performance of all subjects for each list in each set of problems. Thus we have for each set in the group the average performance of all subjects for each of the thirty lists added while vocalizing the vowel "E" and the average performance of all subjects for each of the thirty lists added without the vocalization of the vowel.

From these tables we note again that with a greater number of lists to add the amount of work done while vocalizing the vowel "E" is superior to the amount of work done when not vocalizing the vowel; that this superiority is consistent and reliable from set to set as the high values of the $\frac{D}{\sigma}$ diff's indicate. The group results thus confirm the individual results.

The data are present graphically as practice curves. The first group of graphs (p. 75) presents the data for one place numbers; the second group of graphs (p. 76) presents the data for two place numbers. In each group the upper graph is for the amount of work done while vocalizing the vowel "E," the lower graph for the amount of work done without the vocalization of the vowel. In determining these graphs the following procedure has been employed. From the averages in each table (Table XXVIII and Table XXIX) averages for each consecutive group of six averages have been computed respectively for the lists added with "E" and for the lists added without the vocalization of the vowel "E," for each set of problems. Thus for each set of problems in each of the above tables six major averages have been computed from the thirty averages for work done with the vocalization of the vowel and six major averages have been computed from the thirty averages for work done without the vocalization.

In these tables, according to set of problems therein, the average performances of all subjects for a list added with "E," has been divided by the average performance of all subjects for the corresponding list added without "E." It follows, that for each set of problems we have computed thirty ratios determined respectively by dividing the average performances with "E" by the average performances without "E." In this manner, we have endeavored to determine in terms of ratios of average performances the superiority of work done while vocalizing the vowel "E" over the amount of work done when not vocalizing the vowel.

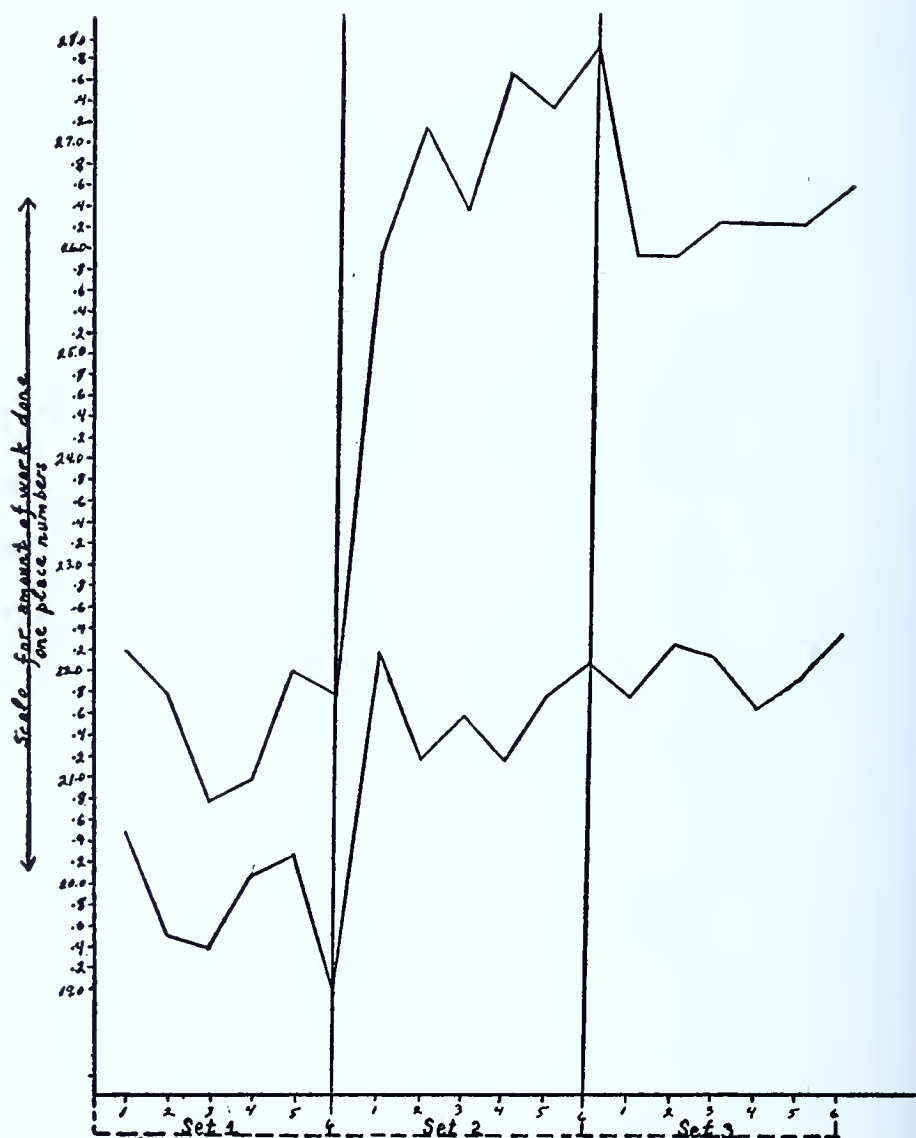


FIG. 3.—PRACTICE CURVES FOR ONE PLACE NUMBERS: THE UPPER CURVE WITH VOCALIZATION OF "E"; THE LOWER CURVE WITHOUT THE VOCALIZATION.

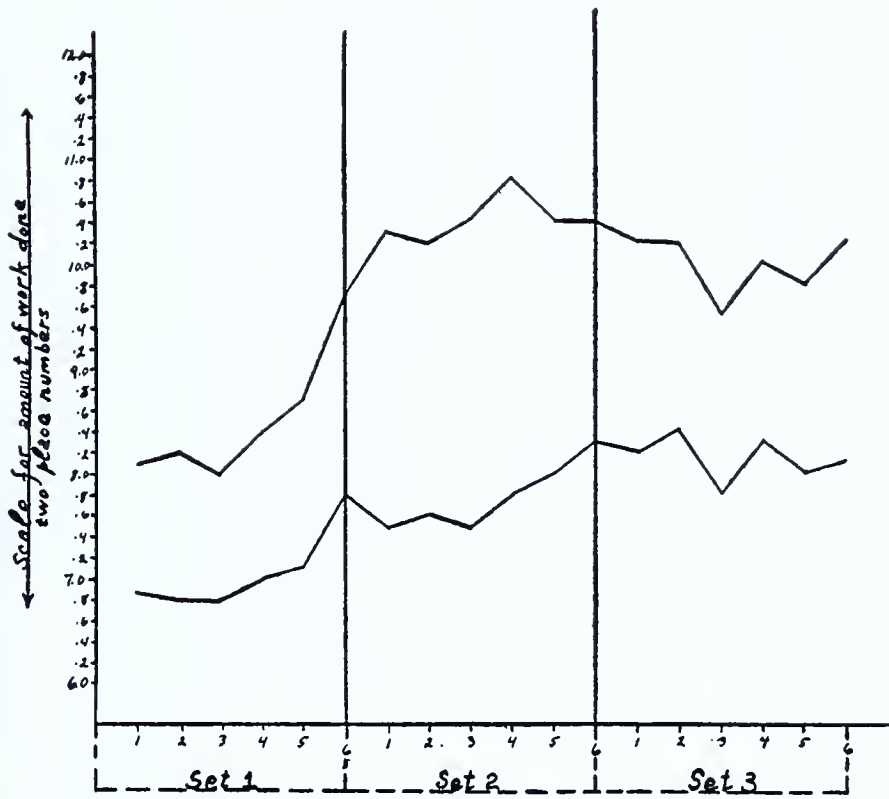


FIG. 4.—PRACTICE CURVES FOR TWO PLACE NUMBERS: THE UPPER CURVE WITH THE VOCALIZATION OF "E"; THE LOWER CURVE WITHOUT THE VOCALIZATION.

TABLE XXX.

RATIOS OF AVERAGE AMOUNT ADDED WITH "E" IN TERMS OF AVERAGE AMOUNT ADDED WITHOUT "E" ÷ ONE PLACE NUMBERS (THIRD GROUP OF SUBJECTS).

<i>Lists</i>	<i>First Set</i>	<i>Second Set</i>	<i>Third Set</i>		
1	1.0124	1.2069	1.2727		
2	1.0930	1.2184	1.1123		
3	1.0305	1.1404	1.2370		
4	1.0976	1.1724	1.1576		
5	1.1625	1.1344	1.1941		
6	1.0909	1.2114	1.1319		
7	1.0915	1.2486	1.1897		
8	1.1494	1.2704	1.1611		
9	1.1333	1.3720	1.2197		
10	1.1132	1.3121	1.1319		
11	1.0813	1.3091	1.2470		
12	1.0588	1.2093	1.1453		
13	1.0854	1.2159	1.2184		
14	1.0867	1.1977	1.1730		
15	1.0680	1.2034	1.1421		
16	1.0182	1.3822	1.2102		
17	1.1523	1.2528	1.1808		
18	1.0061	1.3086	1.2335		
19	1.0952	1.3293	1.1694		
20	.9602	1.2690	1.2761		
21	1.0875	1.1720	1.1751		
22	1.0460	1.2457	1.3165		
23	1.1921	1.2945	1.1124		
24	1.0606	1.2717	1.1749		
25	1.1192	1.3103	1.2120		
26	1.1644	1.3006	1.1257		
27	1.1161	1.1720	1.1075		
28	1.1192	1.2346	1.2147		
29	1.2303	1.3081	1.2917		
30	1.1097	1.3237	1.1943		
Total	32.8313	37.5976	35.7281		
Av.	1.0944	1.2533	1.1909		
σ	.0622	.0679	.0535		
Coef. V.	5.6836	5.4180	4.4922		
$\sigma_{Av.}$	.0114	.0124	.0098		
σ Diff., Diff., $\frac{D}{\sigma}$ Diff. Between Second and First Sets, Second and Third Sets, Third and First Sets.					
<i>Second and First Sets</i>		<i>Second and Third Sets</i>		<i>Third and First Sets</i>	
σ Diff.	.0168	σ Diff.	.0158	σ Diff.	.0150
Diff.	.1589	Diff.	.0623	Diff.	.0966
$\frac{D}{\sigma}$ Diff.	9.4453	$\frac{D}{\sigma}$ Diff.	3.9443	$\frac{D}{\sigma}$ Diff.	6.4373
<i>Variability of Second Set in Terms of First Set</i>		<i>Variability of Second Set in Terms of Third Set</i>		<i>Variability of Third Set in Terms of First Set</i>	
.9533		1.2061		.7904	

TABLE XXXI.

RATIOS OF AVERAGE AMOUNT ADDED WITH "E" IN TERMS OF AVERAGE AMOUNT ADDED WITHOUT "E" ÷ TWO PLACE NUMBERS (FOURTH GROUP OF SUBJECTS).

<i>Lists</i>	<i>First Set</i>	<i>Second Set</i>	<i>Third Set</i>
1	.9608	1.2459	1.1818
2	1.2777	1.5085	1.2879
3	1.1636	1.4386	1.2813
4	1.2105	1.4467	1.2500
5	1.2807	1.2500	1.2537
6	1.1429	1.3793	1.2273
7	1.1455	1.3000	1.1233
8	1.2222	1.2825	1.2923
9	1.3208	1.3934	1.2687
10	1.2500	1.3492	1.1364
11	1.2777	1.2687	1.3226
12	1.2727	1.3548	1.1343
13	1.1923	1.4107	1.2097
14	1.1538	1.4138	1.1613
15	1.0351	1.5087	1.3103
16	1.1695	1.3492	1.1666
17	1.2963	1.4444	1.1618
18	1.0862	1.3710	1.2576
19	1.3200	1.3898	1.2258
20	1.2545	1.3385	1.1857
21	1.1148	1.3065	1.1538
22	1.3019	1.3692	1.1642
23	1.2857	1.3016	1.2969
24	1.2545	1.3226	1.3167
25	1.2105	1.2239	1.1875
26	1.3065	1.2576	1.3387
27	1.2295	1.2727	1.3175
28	1.1666	1.2319	1.1429
29	1.2542	1.2656	1.2581
30	1.2540	1.2424	1.2615
<i>Total</i>	36.4111	40.2316	36.8759
<i>Av.</i>	1.2137	1.3411	1.2292
<i>σ</i>	.0817	.0803	.0702
<i>Coef. V.</i>	6.7315	5.9878	5.7110
<i>σ_{AV.}</i>	.0149	.0147	.0128
<i>σ</i> Diff., Diff., $\frac{D}{\sigma}$ Diff. Between Second and First Sets, Second and Third Sets, Third and First Sets.			
<i>Second and First Sets</i>		<i>Second and Third Sets</i>	<i>Third and First Sets</i>
<i>σ</i> Diff. .0209		<i>σ</i> Diff. .0195	<i>σ</i> Diff. .01967
Diff. .1274		Diff. .1119	Diff. .0155
$\frac{D}{\sigma}$ Diff. 6.0845		$\frac{D}{\sigma}$ Diff. 5.7452	$\frac{D}{\sigma}$ Diff. .7880
<i>Variability of Second Set in Terms of First Set</i>		<i>Variability of Second Set in Terms of Third Set</i>	<i>Variability of Third Set in Terms of First Set</i>
.8895		1.0485	.8484

The statistical treatment of the ratios again confirm our previous findings that for each set of problems the amount of work done while vocalizing the vowel "E" is reliably superior to the amount of work done when not vocalizing the vowel. The present results also confirm the individual results in that the superiority of output is reliably increased in the second set as the high values of the $\frac{D}{\sigma \text{ diff.'s}}$ indicate and that no such

progress holds between the second and third sets. In Table XXX (one place numbers) we note that the third set is reliably superior to the first set for amount of work done while vocalizing the vowel "E." In Table XXXI (two place numbers) we note that though the third set is somewhat superior to the first set for amount of work done with "E" still this superiority is fairly reliable. However, in spite of this fair reliability, the difference in output between the two sets is too small to be taken seriously.

The data of ratios of average performances (average output with "E" divided by average output without "E") are presented graphically. The graph on page 83 is for the ratios of average performances for one place numbers; the graph on page 84 is for the ratios of average performances for two place numbers. The following procedure has been employed in determining the graphs. From the ratios in each table (Table XXX and Table XXXI) averages for each consecutive group of six ratios have been computed. Thus for each set six averages have been computed from its thirty ratios.

Each graph shows clearly that the superiority of amount of work done with "E" over the amount of work done without "E" is greatest with the second set of problems, *i.e.*, during the second sitting.⁸ The diminution in superiority of performance with vocalization during the third sitting, we believe is due to the waning effect of the vocalization of the vowel "E" as a dynamogenic and facilitating influence. In other words, with continued and prolonged practice the type of distraction employed in these experiments begins to lose its dynamogenic and facilitating influence for greater mental activity and probably if continued long enough will lose its dynamogenic effect altogether, thereby causing little or no facilitating influence upon mental activity.

⁸ It will be recalled that the sets of problems were given to each subject at different sittings, at intervals of every other day.

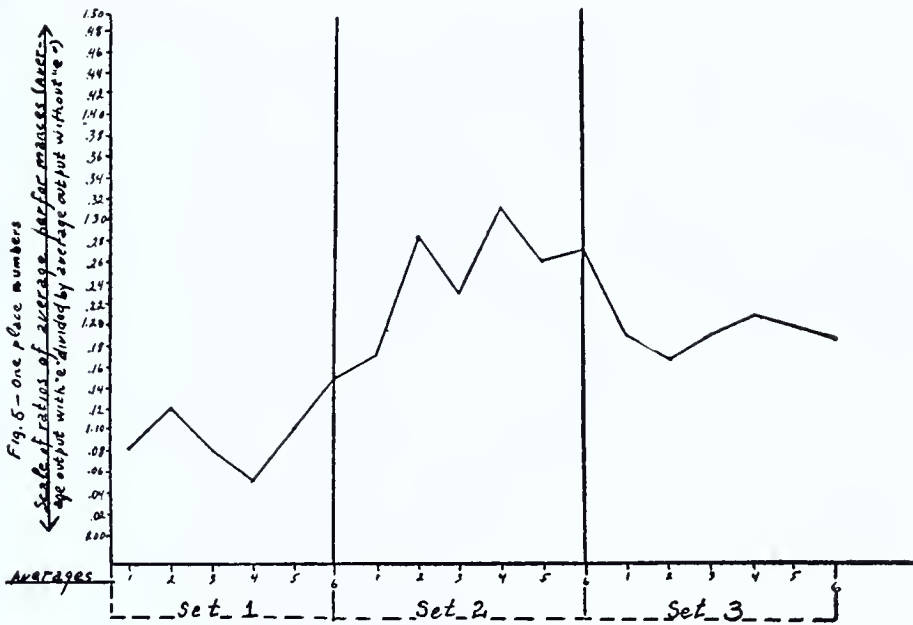


FIG. 5.—ONE PLACE NUMBERS.

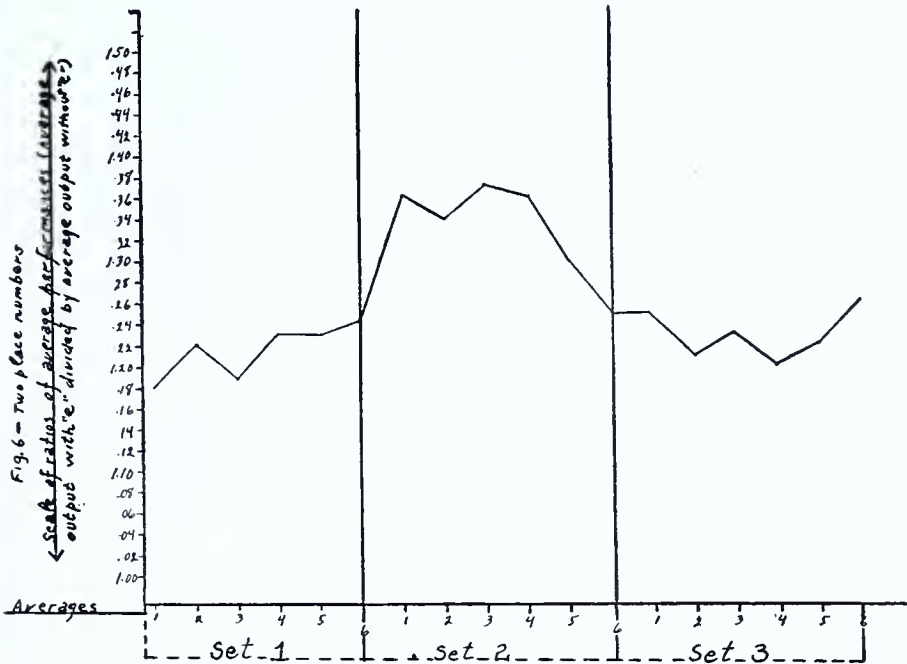


FIG. 6.—TWO PLACE NUMBERS.

TABLES FOR ERRORS

Table XXXII gives the errors for one place numbers; Table XXXIII gives the errors for two place numbers. In drafting these tables we have considered as errors all lists whose sums added were incorrect. Accordingly, if in a set of problems the subject added ten lists incorrectly while vocalizing the vowel "E" and eleven lists incorrectly when not vocalizing the vowel we recorded the subject as having made ten errors while vocalizing the vowel, eleven errors when not vocalizing the vowel.

TABLE XXXII.
ONE PLACE NUMBERS.
Errors.

<i>Subject</i>	<i>First Set</i>		<i>Second Set</i>		<i>Third Set</i>	
	<i>With "E"</i>	<i>Without "E"</i>	<i>With "E"</i>	<i>Without "E"</i>	<i>With "E"</i>	<i>Without "E"</i>
1	11	9	8	9	7	9
2	11	10	9	8	6	8
3	8	9	6	8	7	7
4	9	11	8	10	8	6
5	11	8	9	11	7	8
6	12	11	8	9	8	8
7	9	9	8	10	7	9
8	10	8	12	9	9	8
Total	81	75	68	74	59	63
Av.	10.1250	9.3750	8.5000	9.2500	7.3750	7.8750

TABLE XXXIII.
TWO PLACE NUMBERS.
Errors.

<i>Subject</i>	<i>First Set</i>		<i>Second Set</i>		<i>Third Set</i>	
	<i>With "E"</i>	<i>Without "E"</i>	<i>With "E"</i>	<i>Without "E"</i>	<i>With "E"</i>	<i>Without "E"</i>
1	15	12	10	12	12	12
2	12	7	12	13	7	9
3	11	15	13	12	11	12
4	15	20	10	14	10	14
5	12	14	12	12	12	12
6	15	13	11	14	10	11
7	13	11	11	13	10	10
8	14	12	12	13	10	9
Total	107	104	91	103	82	89
Av.	13.3750	13.0000	11.3750	12.8750	10.2500	11.1250

The size of the error for each list added incorrectly was disregarded.

From the tables of errors it becomes apparent that the differences between the number of errors when vocalizing the vowel "E" and the number of errors when not vocalizing the vowel were too small to be significant. We may state, then, that the efficiency for accuracy under both conditions of experiment was about the same; that the vocalization of the vowel "E" neither increases nor decreases the efficiency for accuracy when adding one place or two place numbers. These results are significant because with the amount (number) of errors equal under both conditions, we are justified in claiming the conclusions deduced from the quantitative results as valid without reservations. Were there a disparity of errors, the conclusions deduced would have to take account of this factor and would render interpretations ambiguous.

C. Experiments Performed upon the Writer as Subject

Since in the case of the writer, the average time for vocalization was less, a correction was necessary.

TABLE XXXIVA.

ERRORS IN ADDING LISTS OF FORTY-FIVE ONE-PLACE NUMBERS.

	<i>With Vocalization</i>	<i>Silently</i>	<i>Aloud</i>
Average	0.5	0.737	0.947
σ	1.36	1.59	1.61
V	272	216	170
σ (Av.)	0.248	0.294	0.294
Average time for vocalization: 26.84.			

TABLE XXXIVB.

DIFFERENCES AND THEIR RELIABILITIES.

	<i>With Vocalization vs. Silently</i>	<i>With Vocalization vs. Aloud</i>	<i>Silently vs. Aloud</i>
D	-0.237†	-0.447†	-0.21†
σ (dif.)	0.385	0.385	0.416
D/ σ (dif.)	0.61	1.16	0.505

† A minus sign for the difference indicates that the quantity of the second condition is larger than the first.

TABLE XXXVa.
AMOUNT IN ADDING LISTS OF FORTY-FIVE ONE-PLACE NUMBERS.

	<i>With Vocalization</i>	<i>Silently</i>	<i>Aloud</i>
Average	35.36	23.86	25.38
σ	3.3166	3.68	3.56
V	9.88	15.0	13.9
σ (Av.)	0.605	0.67	0.649

TABLE XXXVb.
DIFFERENCES AND THEIR RELIABILITIES.

	<i>With Vocalization vs. Silently</i>	<i>With Vocalization vs. Aloud</i>	<i>Silently vs. Aloud</i>
D	11.50	9.98	—1.52
σ (dif.)	0.903	0.887	0.933
D/ σ (dif.)	12.73	11.25	1.63

Summary of Results in Tables XXXIV a and b; XXXV a and b

The significant results to be learned from these two tables are that the vocalization of "E" during the addition of one-place numbers, while causing little and unreliable differences in errors, increases by nearly one-half the amount added, the difference being completely reliable. The amount added by silent addition is greater than by loud addition, but the differences are small and insufficiently reliable.

TABLE XXXVIa.
ERRORS IN ADDING FIRST GROUP OF LISTS OF TWO-PLACE NUMBERS.

	<i>With Vocalization</i>	<i>Silently</i>	<i>Aloud</i>
Average	1.3	1.86	2.44
σ	5.226	4.05	6.01
V	402	218	248
σ (Av.)	0.955	0.74	1.11

Average Time with Vocalization: 27.13 sec.

TABLE XXXVIb.
DIFFERENCES AND RELIABILITIES.

	<i>With Vocalization vs. Silently</i>	<i>With Vocalization vs. Aloud</i>	<i>Silently vs. Aloud</i>
D	-0.56	-1.14	-1.58
σ (dif.)	1.208	1.464	1.34
D/ σ (dif.)	0.464	0.73	0.4325

TABLE XXXVIIa.
AMOUNT IN ADDING FIRST GROUP OF LISTS OF TWO-PLACE NUMBERS.

	<i>With Vocalization</i>	<i>Silently</i>	<i>Aloud</i>
Average	9.66	6.6	6.95
σ	3.307	1.03	1.135
V	34.2	15.6	16.32
σ (Av.)	0.605	0.188	0.2075

TABLE XXXVIIb.
DIFFERENCES AND THEIR RELIABILITIES.

	<i>With Vocalization vs. Silently</i>	<i>With Vocalization vs. Aloud</i>	<i>Silently vs. Aloud</i>
D	3.000	2.717	-0.28
σ (dif.)	0.625	0.64	0.28
D/ σ (dif.)	4.8	4.23	1.00

Summary of Tables XXXVI a and b; XXXVII a and b

As before, the vocalization of sound "E" while adding two-place numbers caused no differences in number of errors, but increases the amount added by nearly one-half, the differences being completely reliable. Loud addition again is less efficient than silent, but the differences are small and insufficiently reliable.

TABLE XXXVIIIa.
ERRORS IN ADDING SECOND GROUP OF LISTS OF TWO-PLACE NUMBERS
WITH "PE" VOCALIZED.

	<i>With Expulsions of "Pe"</i>	<i>Silently</i>	<i>Aloud</i>
Average	0.43	0.912	0.0382
σ	2.338	2.35	0.159
V	565	258	416
σ (Av.)	0.426	0.429	0.029

Average Time with Expulsion: 11.48.

TABLE XXXVIIIb.
DIFFERENCES AND RELIABILITIES.

	<i>With Expulsions of "Pe" vs. Silently</i>	<i>With Expulsions of "Pe" vs. Aloud</i>	<i>Silently vs. Aloud</i>
D	-0.482	0.398	0.874
σ (dif.)	0.605	0.427	0.43
D/ σ (dif.)	0.798	0.918	2.03

TABLE XLa.
AMOUNT IN ADDING SECOND GROUP OF LISTS OF TWO-PLACE NUMBERS
WITH EXPULSIONS OF "Pe".

	<i>With Expulsions of "Pe"</i>	<i>Silently</i>	<i>Aloud</i>
Average	6.33	3.38	3.615
σ	1.135	0.55	0.369
V	17.9	16.25	10.2
σ (Av.)	0.207	0.100	0.0674

TABLE XLb.
DIFFERENCES AND RELIABILITIES.

	<i>With Expulsions of "Pe" vs. Silently</i>	<i>With Expulsions of "Pe" vs. Aloud</i>	<i>Silently vs. Aloud</i>
D	2.954	2.718	-0.235
σ (dif.)	0.209	0.2145	0.1175
D/ σ (dif.)	14.12	12.62	2.00

Summary of Tables XXXII a and b; XL a and b

As in the previous two series the results show that the expulsion of "Pe" increases by more than one-half the amount added with little differences in errors.

EXPIRATION CURVES.

The following groups of curves give, for two subjects, (1) expirations curves⁹ while vocalizing the vowel "E" and adding a list of numbers; (2) expiration curves when vocalizing the vowel without adding a list of numbers. For each subject an expiration curve for each of these conditions is given. The

⁹ Sumner's pneumograph was used; for description of apparatus and methods of employment see "Psychological and Physiological Apparatus and Supplies" pp. 213-21; C. H. Stoelting and Company.

curves are exact reproductions of kymographic records. They represent typical curves.

These curves are significant because they show that the vocalization of the vowel was steady and continuous (*i.e.*, without interruption) under each of the above conditions until the volume of air inspired from the spirometer had been expired. This was a condition which was forced upon all subjects. No subject failed to observe this condition. The similarity of the curves is also significant; it shows that the muscular apparatus involved was functioning in the same way when vocalizing with addition and when vocalizing without addition.

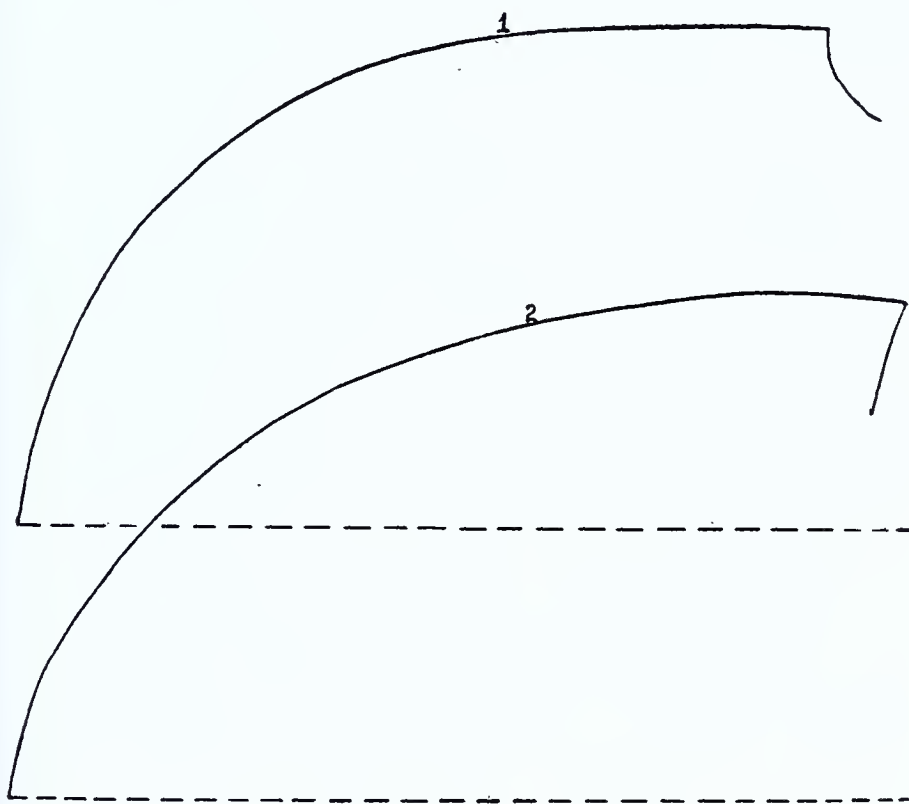


FIGURE 7.

1. Curve of Expiration for 250 Cu.In. of Air While Vocalizing the Vowel "E" and Adding a List of One Place Numbers.
2. Curve of Expiration for 250 Cu.In. of Air While Vocalizing the Vowel "E" Without Adding a List of Numbers.

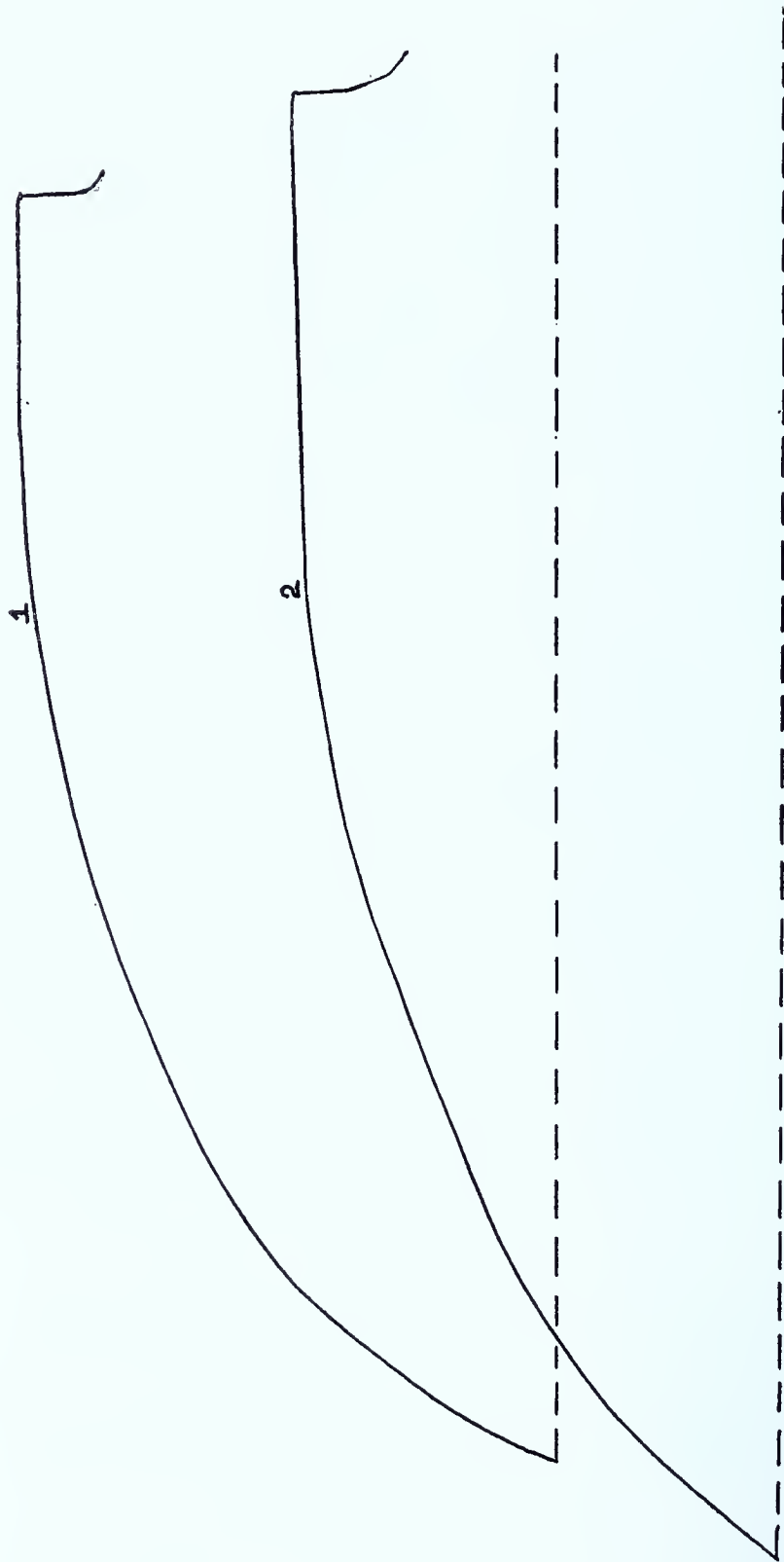


FIGURE 8.

1. Curve of Expiration for 250 Cu.In. of Air While Vocalizing the Vowel "E" and Adding a List of Two Place Numbers.
2. Curve of Expiration for 250 Cu.In. of Air while Vocalizing the Vowel "E" Without Adding a List of Numbers.

CONCLUSIONS

1. It is possible to perform such intellectual tasks as adding columns of figures and memorizing numbers or nonsense syllables while steadily intoning a vowel sound at a constant pitch. All repetitions of the experiment, with forty subjects, agree to this extent. The steady laryngeal and buccal activity did not seriously handicap the intellectual operations. Since the vocalization was never interrupted during the performance of the intellectual task, we are sure that the two processes went on simultaneously. Since the intellectual processes here employed are certainly such as make use of inner speech, the conclusion is justified that vocalization and inner speech unrelated to the vocalization can go on simultaneously with little or no mutual interference.

2. In a brief series of trials at combining the steady vocalization with intellectual operations, some individuals show some facilitation of the intellectual operation, and others show some degree of inhibition or interference. The group average in such a brief experiment showed no reliable difference between the intellectual performance with and without intonation of the vowel.

3. If the practice in performing intellectual tasks during the vocalization is continued, a facilitating effect of the vocalization soon makes its appearance. This has been found true in each of 17 individuals tested over a prolonged period of experimentation. The group difference between the performance with and without vocalization is in this case perfectly reliable.

4. With still further repetition of the performance, the facilitating effect of the vowel intonation shows signs of waning, though it was still strongly in evidence at the end of 90 double performances (with and without the vocalization), occupying in all ——— of the subject's time.

5. The errors committed in adding were no more frequent during the vocalization than during the control performance; so that the advantage of the performance with vocalization is not due to any loss of accuracy.

6. Similar facilitation was obtained in one subject when a continued repetition of the syllable "Pe," was substituted for the intonation of the vowel.

7. The increase in efficiency observed when vocalizing is certainly the result of some facilitation or dynamogenesis which, however, manifests itself in any considerable degree only after some practice in the simultaneous repetition of the main and distracting activity. There is no doubt that the vocalization increases not only the muscular tension of the speech apparatus directly involved but also to a lesser degree the tension of other muscles not directly involved. In this respect, our findings are in marked agreement with those of Bills who found that muscular tension increases the efficiency of mental work such as is involved in addition or memorizing (see historical review, page 5).

8. Our findings are also strikingly in agreement with experimental work on conditioning, where the simultaneous activation of the unconditioned and conditioned reactions results in an increase of the response to the unconditioned stimulus by the simultaneous activation of the conditioned stimulus.

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